Investigations on the Spike-Disease of Sandal.

I. RESUMÉ OF OBSERVATIONS MADE TO DATE.

II. REPORT OF PROGRESS MADE DURING THE QUARTER ENDING 30th JUNE 1931.

The present publication being the first of the series, it is considered desirable to present, at the outset, a brief statement of the more important observations so far recorded in connection with the spike-disease of sandal.

1. The spike-disease of sandal is a definite communicable disease caused by some hitherto unknown agency.

2. The primary infection is erratic. Generally, it starts from within a few miles or beyond, but sometimes it appears suddenly from even 100 miles off and more. This distant attack has so far been inexplicable.

3. In Madras Presidency and Coorg, the primary infection generally starts in either a cultivated or *pisari* land or within a mile of it.

4. The direction of spread, as seen from the consolidated maps of Coorg, Mysore and Madras, appears to be East, North-East.

5. A spiked tree has never been known to recover.

6. The disease generally manifests itself when the new flush of leaves appears. The infected but apparently healthy trees can be made to manifest the symptoms at any time by pruning the branches.

7. The first signs of the disease are generally seen in solitary twigs or branches while the other parts remain apparently healthy. Occasionally even whole trees show the symptoms all at once.

8. The time taken for a spiked tree to die varies from as low as 2 months to as high as 36 months; saplings of ½ to 3 inches girth have taken from 2 to 13 months to die whereas bigger ones have taken from 8 to 36 months.

9. The disease usually appears to affect saplings above 4½ years of age when they would have flowered and fruited at least once. Beyond this age, the plants and trees are affected irrespective of age.

10. Extremely sickly and more or less stag-headed trees appear to remain generally free from spike. This should not, however, be taken to mean that sickly trees are immune to spike.

11. Saplings under cover or suppression are more susceptible to the disease than those grown completely in the open.

12. The incidence is at its highest in any month between May and July.

13. Spiked twigs do not bear flowers.

14. The healthy part of a partially spiked tree flowers and seeds profusely.

15. Seeds from healthy parts of spiked trees give healthy seedlings. This accounts for the plentiful natural regeneration of healthy sandal even in badly infected areas.

16. In lantana-infested spiked areas, removal of lantana decreases the incidence.

17. Transmission through tissue transplantation, *i.e.*, by bark-graft or by leaf-insertion gives the highest percentage of success. The most susceptible place for infection is the Cambium region.

18. Transmission through roots appears to be limited and thus accounts for the occurrence of a large number of healthy sandal trees in close proximity to diseased ones.

19. Mere contact of diseased parts with the healthy plants does not induce the disease. Even plants planted in pits from which spiked trees had been pulled out do not get the disease except in the usual course.

20. The period of incubation or, in other words, the period that elapses between the date of grafting and the date on which the outward manifestation takes place, appears to depend on the dose of infection, the age and hosts of the sandal being the same. Thus, with $2\frac{1}{2}$ year old plants, having *Acacia suma* as hosts, a single graft of area 0.12 sq. in., induced the disease in 117 days while 6 grafts with a total area of 0.72 sq. in., induced the disease in 54 days.

21. Immunity of sandal to spike appears to depend on the quality of host plants.

22. Diseased trees are generally associated with either damaged or dead hosts.

23. The phyllody in spiked trees is rare and is said to be due to excess of starch in the stem, twigs and leaves.

J. E. M. MITCHELL.

Experiments conducted by the Madras Forest Department in co-operation with the Indian Institute of Science.

I. Cause.—1. Data are being collected to study the nature of the relation betwen field crops and primary infection. The results so far obtained, though meagre, indicate the possibility of infection being carried through field crops. 2. *Is fire one of the contributing causes?*—The plots were started during March—April 1931. The percentage of incidence obtained for May and June 1931 is:—

	May	June
Burnt plot ..	1.9	5.3
Control plot ..	0.5	7.9

II. Nature of the disease.—1. In a newly spiked area (Manchi unreserve) which contains about the same number of plants and trees belonging to each one of the different girth classes up to 40″ and in which only 84 trees were spiked till May 1931, the following numbers became infected in each girth class:—

Girth class, inches	Number infected	Girth class, inches	Number infected
0— 3	0	18—21	9
3— 6	1	21—24	13
6— 9	0	24—27	7
9—12	4	27—30	7
12—15	11	30—33	7
15—18	17	33—36	6
		36—39	2

2. Grafting in higher girth classes has not, so far, yeilded any useful information.

III. Treatments for preventing the spread of the disease.—1. For the present, treatment with Atlas solution has been tried, but not with much success. The nature of the action of the solution is being determined and the method of its application worked out by the Institute. 2. Manuring the area with lime has given a somewhat useful result in a locality containing a large number of host trees, while in a scrub jungle with practically no tree growth, the addition of lime appears to favour the spread of infection. 3. In the case of plants under sylvicultural conditions, girdling below the point of manifestation of the disease does not appear to prevent the spread

of infection in the same plant. On the other hand, in the case of pot-plants on which the infective principle was introduced by grafting, it has been found possible to prevent the spread by girdling. It appears from the above that the points of actual infection are not indicated by those at which the disease manifests itself in the case of forest plants.

IV. Prevention.—The experiments in connection with the prevention of the disease have been carried out on a small scale. 1. The lime deficiency in the soil has been artificially made good and sandal raised under all favourable sylvicultural conditions in the midst of a severely spiked area. The oldest plants are only 1½ years of age. 2. The five-year old, artificially raised plants, which are still apparently continuing healthy have also been manured with lime and the results are awaited.

J. E. M. MITCHELL.

Coorg Experiments.

The following general observations seem of interest :—

1. Though the disease was first observed in Fraserpet in 1899, there are a considerable number of mature sandal trees around Fraserpet Fort which have remained healthy all these years. Special observation of this area during the last 3 years has revealed no fresh attack. The area is almost free from lantana.

2. In 1920, a case of spike was noticed in the old (about 1883) sandal plantation in front of the Dubare bungalow ; the infected tree was removed and no other tree has since been infected. At some unknown date all the host-plants were removed from this plantation which is now stag-headed.

3. *Acacia suma* was introduced as a host into the Banawara (1882-86) plantations in North Coorg apparently about 1918 and the Balumani (1880-83) plantations in South Coorg by about 1915 (no records of date can be found). Both these plantations have now been almost wiped out by spike. The case of the Balumani plantations is curious as it is reported that now there is no other spiked area within about 4 miles. The adjoining lands are under cultivation. Another interesting fact is that though sandal exists in the adjoining *pisari* (unreserved land) it is reported to be quite free from spike.

4. There are 34 sandal trees in the Coorg Timber Depot at Hunsur most of them having *Cassia siamia* as hosts. Though Hunsur is reported to be a very heavily spiked area and spiked trees occur only about 3 or 4 furlongs away, no tree in the depot has been attacked.

5. It is reported that for a number of years past no new areas in Coorg have been attacked by spike-disease. This statement should be accepted with some reserve since no definite data are available.

H. A. H. G. HICKS.

Some Recent Experiments conducted by the Indian Institute of Science.

Field Experiments.—1. *Manurial plots.*—A critical study of the results accumulated during the last two years and a half, has not revealed any marked difference with regard to disease-incidence among the sandals stocked in various plots treated in different ways. There is no striking agreement between the two sets of experiments conducted at Jawalgiri and at Aiyur. The value of these areas consists in (1) the circumstance that we now possess a valuable and careful record of nearly 6,000 sandal trees, of various girth classes, and (2) the fact that the plots viewed as observation areas have given us valuable data with regard to seasonal variation in the incidence of disease. In addition to these two aspects, some general conclusions can be drawn :—(1) Digging up the soil involving æration, a well-known cultural practice, has a beneficial effect on the growth and resistance of sandal. (2) Sandal plants treated with lime present a healthier appearance, and withstand conditions of drought better, and generally bear bigger fruits. (3) Percentage of disease-incidence in the manurial plots at Aiyur is lower than the corresponding figure for Jawalgiri. Comparatively deep-rooted and vigorous hosts present in Aiyur probably account for the relative resistance of the sandal plants stocked in Aiyur. An entomological survey of the manurial plots is necessary for a correct interpretation of the disease-incidence data, as the high percentage of incidence in Jawalgiri may be attributed to a relative abundance of insect vectors. So far as the virulence of the disease is concerned, comparative grafting trials have shown that infective tissues from the Jawalgiri area are more virulent, which presumably accounts for the epidemic spread of disease in that area.

2. *Grafting under sylvicultural conditions: (a) On big trees.*—Grafting under sylvicultural conditions were carried out at Jawalgiri and Coorg on small saplings in November 1928. The importance of carrying out grafting operations on sandal trees of higher girths, with a view to determining the period before the manifestation of disease symptoms, was emphasized at the Fifth Spike Conference. In accordance with this suggestion, 500 plants of various girth classes have been grafted in Aiyur by the patch and leaf-insertion methods. (*b*) *On plants reputed to be disease-resistant.*—Sandal trees in the Mahadeswarangudi area which have remained healthy during the last fifteen years were grafted by the leaf-insertion method. Of the 30 insertions not a single leaf remained alive. They were actually pushed out by vigorous callous formation. It is difficult to say if this remarkable phenomenon is due to the immunity of the stocks. Further experiments are in progress to confirm this important observation.

3. *Regeneration plots.*—Ecological surveys have shown the predominance of certain species of plants and the exclusive presence of certain other species in the healthy area. The seeds of such plants have been collected, and sandal plants have been raised with these host-plants singly and also in combinations of two or three. The immunity of such sandal plants are being tested by grafting them quantitatively by the leaf-insertion method. Among the hosts which have imparted comparative immunity to sandal are, *Melia indica*; *Murraya kœnigii*; *Cassia siamia*; *Semicarpus anacardium* and *Dodonœa viscosa.* The effect of other host-plants on disease-resistance in sandal is being determined.

Sandal plants are made susceptible to disease when they are nourished by certain types of host-plants. The flora of heavily infected areas have been raised individually in pots in association with sandal plants. Experiments are in progress, but definite results have been obtained in some instances. *Acacias* in general, *Pungamia glabra*, *Lantana camara* and *Cajanus indicus* have been definitely found to render the sandal particularly susceptible to disease.

It is clear therefore that the flora of sandal areas could be divided into two groups, the first group consisting of those species which impart to the sandal plant the quality of resisting disease and the second group comprising all those host-plants which render sandal susceptible to disease.

With a view to establishing the efficiency of these two groups of host-plants under sylvicultural conditions, regeneration plots have been opened in Jawalgiri and two methods of regeneration have been adopted, (1) Sowings in the ortkodox way and (2) Transplantings on mounds. One set of sandal plants will be fed with favourable hosts belonging to the first group while the other set will be provided with unfavourable or predisposing host-plants. The results, if successful, would lead us to the most rational and effective way of combating the spike-disease of sandal.

4. *Studies in the natural dissemination of the disease: Sporadic attack and radial spread.*—Any theory proposed to explain the natural spread of spike-disease should convincingly account for the two types of spread which have been observed : first in the sporadic attack which takes place in unexpected areas miles away from any source of infection. This long distance carriage of disease, without touching the intervening areas of sandal, may be termed the primary attack. The second type is represented by the radial spread of disease around the central site of primary infection. This may be termed the secondary spread.

The experimental fact that disease spreads through haustorial connections, partly explains the secondary spread; and it should be emphasized that this does not fully account for the whole of the secondary spread that occurs. It must also be addmitted the spread of disease through roots under sylvicultural conditions is possibly very small, since the percentage of

effective artificial transmissions so far achieved by this method in the laboratory under controlled conditions, does not exceed 8. The secondary spread of disease is in consequence largely effected above ground through some agency, as yet undetermined.

The pollen theory.—The consolidated map which comprises all the old, the more recent and new spike areas, roughly indicates that spike tends to spread from S.S.W. to N.E.E. Hart and Rangaswami (*Indian Forester*, 1926, 373) state that the spread of spike has taken an East-North-Eastern direction towards the Salem District, corresponding to the general direction of the South-West monsoon. They postulate that pollen from the flowers of partially spiked trees when transferred to those of healthy sandal plants in the process of fertilization, is the causal entity. In support of this hypothesis they advance their observation that sandals under natural conditions have never become spiked before flowering. If confirmed by a more extensive survey, this observation would have great significance, not only on the biochemical but also on the entomological aspects of the problem. It must, however, be admitted that the pollen theory does not adequately explain primary attacks of spike, and further no experimental transmissions have been effected through pollen.

The insect vector theory.—An insect vector theory of disease transmission has been accepted as the official view since it was believed that it would explain both the sporadic and the continuous spread of spike. In postulating this theory several assumptions were made, the principal ones being (1) that the disease is transmitted by sucking insects; (2) that these sucking insects are either strong winged, capable of independently traversing long distances at a stretch, or very minute (*cf.* lac insects) and blown by wind or carried by birds to long distances; (3) that the infective entity has a specific relationship with the insect vector which becomes viruliferous after feeding upon a spiked plant, and (4) that the vector remains infective for a considerable period. The assumptions do not seem justified in the light of recent work which points to the fact that tissue-transplantation is the more probable method of transmission occurring in Nature. It is highly improbable that the disease will ever be transmitted through sap-sucking insects, in view of the experimental fact that it has not been possible to transmit the disease through injection of sap. The tissue transplantation theory is based on the solid foundation of direct experiment and extensive observation, but this theory while being eminently suited to account for the secondary spread does not explain the primary attack satisfactorily.

Sap-injection *versus* **Tissue-transplantation.**—Contradictory arguments have been advanced with regard to each of the above two hypotheses. In support of sap-injection, it is contended that virus diseases are known to be borne only by sucking insects and therefore it is highly probable that spike also is transmitted in a similar manner. It is also held that the disease is carried by

a specific vector on the ground that (1) the disease is seasonal and (2) the spread is slow. Disease transmission, if it were merely mechanical, would involve a large number of species and in consequence the disease would spread rapidly in an epidemic form. The cricumstance that the artificial sap-injection has been a thorough failure constitutes a formidable obstacle to acceptance of a sap-injection theory. The fact that other diseases are carried by sap-sucking insects does not form a sound argument for extending the analogy to spike-disease. There are several diseases of the virus group in fact, which have not been transmitted through sucking insects. Peach yellows and peach Rosette are typical instances in point. The question of the disease being seasonal is misleading. We can only say that the manifestation of disease is seasonal. We do not know the season in which the actual infection occurs. Assumptions that the infection takes place 45 days or three months before the manifestation of symptoms are entirely unjustified. The comparative slowness of spread of disease obtaining under sylvicultural conditions, really means that sandal plants do not easily succumb to disease. Even under laboratory conditions, the number of successful transmissions to date works out to about only 50 per cent. It is not necessary that every infected plant should succumb to the disease. Factors of resistance and immunity play a great rôle in preserving large number of sandal trees from spike.

Tissue-transplantation theory has the solid support of significant experiment and extensive observation. Hundreds of artificial transmissions have been effected by tissue grafting, and even tiny pieces of infective tissue are found adequate to transmit the disease. The mandibular and ovipositing appendages of insects are structurally adequate for carrying pieces of infective tissue while the biting, scratching and ovipositing habits of certain insects render the transplantation of these particles of tissue into the susceptible region, imminently successful. It must be emphasized, however, that all insects cannot achieve this distinction of being able to transplant tissues, as many might imagine. The success of the operation is limited by the length of the appendage, the mode of penetration and insertion into the plant tissue and the form and structure of the transplanting organ. Further work is being done on the ideal form of instrument for successful transmission, in relation to insect organs.

Study of scars.—Extensive observations on the natural and artificially induced scars have been made both in the field and in the laboratory. The possibility of tissue-transplantation is clearly shown by some of the characteristic scars naturally found. A classification of these scars in relation to (1) the responsible insect, (2) the size and shape, (3) the depth of penetration, (4) the particular appendage used in making the scar and (5) the physiological operation, should be attempted and a close study of the reaction of the plant to these various types of injury should be made. A

histo-chemical investigation of the changes induced in the plant at the site of injury is also necessary. These scars have been found extensively on *Lantana*, *Scutia indica*, *Z. œnoplia*, *Acacia pennata*, *Pterolobium indicum*, *Odena sp.?* *Acacia lencophlia*, *Phyllanthus polyphyllus*, *Erythroxylon mongynum* and *Memicylon* have been very sparingly attacked. A study of the fresh scar is being made during the present season to ascertain whether any extraneous tissues are transplanted into the wound inflicted on sandal.

Some properties of the causal entity of spike.—A few properties of the causal entity *in vivo* have been determined. It appears to be killed when infective tissues are heated in a water-bath at 45°C. for 10 minutes, and by the temperature of the liquid air. The tissues retain their infectivity for three to four weeks provided they are kept moist. It appears to be sensitive to changes in hydrogen-ion-concentration, the optimum safety range lying between P_H 4 and P_H 5. This singnificant point perhaps explains why some of the resistant varieties of sandal do not succumb to artificial grafts.

M. SREENIVASAYA.

Laboratory Experiments.

1. A biochemical study of the tissues and tissue-fluids of healthy and spiked sandal.—In view of the very definite physiological disturbances induced by the disease, it was of considerable interest to study the sap from healthy and diseased leaf-tissues. Since the symptoms of the disease are first exhibited by the leaves and since the leaves are the seat of active metabolism, the changes in the leaf-tissues were studied in detail. It was noted that the spiked specimens were distinctly more acid, and contained more of soluble materials and less of mineral nutrients than the corresponding healthy ones. In the case of specimens from partially spiked trees, the results were found to be reversed. This apparent anomaly is probably due to certain other factors such as age and stage of the disease.

A chemical analysis of the various specimens brought out, significantly, the fact that the diseased leaf-tissues contained greater amounts of total nitrogen and starch, but less of lime than the corresponding healthy ones. The above difference was found to be true irrespective of the stage of the disease or the age of the plant, so that it was possible to diagnose the disease biochemically by determining the ratio of calcium to nitrogen.

2. Biometric measurements.—The symptoms of the disease are so well defined that generally there is not much difficulty in identifying the malady in a plant. Recently, however, in some cases, the symptoms could not be

easily observed. Only chemical methods have, till now, provided useful diagnostic indices for distinguishing a diseased tree from a healthy one (Varadaraja Iyengar, *J. Indian Inst. Sci.*, 1928, **11A,** 97). Since the processes involved in such determinations are, however, long and difficult to be carried out on the field, it was considered desirable to develop a reliable quantitative method that can be adopted rapidly even under forest conditions. It was further hoped that such a method might be greatly helpful in (*a*) characterizing the several stages of the disease and correlating them with the different physiological changes, (*b*) indicating the effect of soil and weather conditions on the progress of the disease and (*c*) furnishing early evidence for the adoption of measures necessary for preventing further spread of spike. Since the more prominent symptoms are visible in the leaves and twigs, physical measurements of specimens from trees in health and in different stages of the disease were undertaken.

The maximum length (L), breadth (B) and length of stalk (P) of a large number of leaves of trees, from different areas, in conditions of health and various stages of the disease as determined by chemical methods (*J. Indian Inst. Sci.*, 1929, **12A,** 295) were carefully measured. Some useful relations were obtained from the above and are presented in the following table :—

Condition of the plants	P in m.m.	L/B	$\frac{L-P}{B}$
Healthy	11.3	2.5	2.2
Spiked	2.55	4.5	4.1

In the case of twigs, the averages of internodal distances were found to vary between 16.5 m.m. and 29 m.m. in the healthy samples and between 3.5 m.m. and 9.8 m.m. in the spiked ones.

The foregoing observations have brought out striking differences and suggest that by merely making a number of physical measurements, it may be possible to determine the condition of a tree, where doubts are raised regarding its healthiness.

As an instance of the application of biometric measurements for diagnosing the condition of a tree may be mentioned the case of a sandal plant in Denkanikota, the leaves of which were very small and which in consequence was suspected to be spiked. The measurements showed however, that the leaves were perfectly healthy. Similar specimens in doubtful condition were encountered in Coorg and in a like manner identified to be perfectly healthy.

Attempts are being made to correlate physical measurements with the proportions of certain chemical constituents like calcium and nitrogen.

3. Physiological factors of disease-resistance.—Resistance to disease in plants may be two-fold, (*a*) physical or morphological and (*b*) physiological or biochemical. In the former, the plant is protected from an external attack by special tissue formation such as cork while, in the latter, some chemical entity or entities may accumulate or diminish rendering the plant resistant to attack. Organic acids and tannins come under the second category. Qualitative and microchemical studies of the acids have revealed a distinct difference in this entity between spiked and healthy leaves. A quantitative study is in progress.

4. Studies upon the virus nature of spike.—In view of (*a*) the communicable nature of the disease, (*b*) apparent failure in tracing it to bacteria or fungi and (*c*) the discovery of X-bodies in the diseased leaf-tissues of sandal and *Vinca rosea*, spike disease of sandal has been classified as a virus disease. Detailed microscopical study of the healthy and diseased tissues of sandal, *Z. œnoplia* and *Dodonæa viscosa* is in progress to throw further light on the nature of the infective principle.

5. Season.—Season appears to have a similar effect on both healthy and spiked plants.

6. Spread of the disease.—The first record of the disease was made by McCarthy in 1898, when he noticed it in Fraserpet. The location of other diseased areas with reference to this place, lies on either side of North-Eastern direction. Apparently the spread in Mysore State is within this limit. Records have shown that individual trees in distant localities have independently exhibited the symptoms. It is difficult to explain normally how this takes place. But there are some observations which may help to explain it indirectly. It is well known that besides sandal, there are a large number of species belonging to several orders exhibiting spike-like symptoms. Some of them are known to occur in spiked areas and the chief among them is *Z. œnoplia*. I have observed, of late, that leaves of several plants including sandal and *Z. œnoplia*, both healthy and diseased, show similar marks of being bitten by insects. The possibility of explaining spreads by such agency is under investigation. The way in which the disease spreads in any one area or locality also points to the possibility of root transmission besides the above-mentioned one.

Whatever be the nature of the carrier of infection, there are several factors which have some relation to spike. Perhaps, the chief among them is the occurrence of lantana. It is a somewhat strange coincidence that lantana was introduced into Coorg almost at about the time when McCarthy reported to the existence of spike. Experiments conducted by Tireman in Coorg and latterly by Mitchell and others in North Salem, have definitely shown that the removal of lantana decreases the rate of incidence. Among other possible predisposing factors may be mentioned fire, unfavourable hosts, etc.

A. V. VARADARAJA IYENGAR.

Entomological Studies conducted by the Forest Research Institute, Dehra Dun.

Field work.—During the first half of 1930, various methods of collecting quantitative samples of the insect fauna of healthy and diseased sandal foliage were tested with the object of standardizing a procedure that would give data on the composition, the relative abundance of the various components, their specific identity and the selection of insect species for preliminary biological and experimental studies. Based on the preliminary experience, a revision of the methods of the field survey was undertaken and in August 1930, twenty-one sample plots were started in Jawalgiri, Aiyur and Fraserpet, to which subsequently seven sample plots in Kottur (Vellore) were added. Collections on a quantitative basis, are made in each plot daily by temporary field assistants stationed at these places and are forwarded to Dehra Dun for study.

Biological studies.—These have restricted the consideration of possible vectors to a group of 19 species of sap-suckers belonging to the order, *Hemiptera-Homoptera*, 3 species of *Thysanoptera* (Thrips), one species of *Acarina* (Red-spider) and 2 species of *Molluscs* (Snails). In view of recent field observations, three species of defoliators belonging to the family of *Curculionidæ* (Wheevils) have been added to the above.

It has been observed that the leaves of spiked sandal are eaten by a curculionid in a particular manner, which in certain cases, amounts to partial defoliation. The leaves of healthy sandal trees are also eaten in precisely the same manner as the diseasd leaves, and it has further been observed that the leaves of many other trees like *Canthium didymum*, *Scutia indica*, *Zyzyphus œnoplia*, *Pterolobium indicum*, *Webera corymbosa*, *Memicylon sp.*, *Flacourtia sp.*, *Lantana*, *Toddalia sp.*, *Albizzia sp.*, *Randia dumetorum*, *Acacia sp.*, *Opilia sp.*, *Eleodendron sp.*, *Dodonæa viscosa*, *Jasmininum sp.*, *Bauhinia racimosa*, *Fleuggia sp.*, *Anogeissus latifolia* and others, all peculiar and belonging to the undergrowth strata of spiked and healthy sandal-forest areas, are also eaten in the same manner as the leaves of healthy and diseased sandal. Moreover, the spiked leaves of *Zyzyphus œnoplia* and *Scutia indica* are also eaten in precisely the same manner. Observations have been made on only four species of *Curculionidæ* hitherto, of which *Sympiezomias cretaceus*, *Dereoderus sparsus* and *Myllocerus sp.*, are considered to be impoitant. These beetles are long lived. The beetle of *S. cretaceus* may live and feed actively for over eight months.

Life-history studies.—The life-histories of several species of Homopterous sap-suckers, Lepidopterous and Curculionid defoliators and others, have been studied and some are under observation. Continuous feeding for two

months by large numbers of *Petalocephala sp.*, and *Sarima sp.*, and for five months by large numbers of *Lecanium nigrum*, may cause dying-back of a sandal branch. The general condition of stag-headedness seen in sandal-forests is, it is believed, due to the feeding action of these species and other sap-sucking insects.

The fact that the symptoms of the spike-disease have been artificially produced in healthy sandal plants only by grafting, places the sap-sucking insects in a lower rank as transmitters of the disease; but the possibilities of infection through them are not entirely excluded. Under field conditions, insect species suspected as carriers of the disease, were fed for 8 days on diseased plants and then transferred to healthy plants inside sleeves or muslin cages. Twenty-nine such experiments with *Petalocephala sp.*, *Moonia variabilis*, *Acropona prasina*, *Sarima sp.*, and *Sympiezomias cretaceus* are under observation since November 1930. None of the first four species have yielded any results so far.

Some recent experiments.—A batch of *Sympiezomias cretaceus* beetles, after having been fed for 8 days on a spiked plant in my field sleeve experiments begun on the 5th December 1930, was allowed to feed on five healthy sandal plants in pots for 2½, 5, 15, 25 and 112 days. This experiment was conducted with the same batch of beetles throughout and after the feed, the sleeves being retained on the healthy plants for a period of 4—5 months.

The spike-fed beetles have communicated in healthy sandal plants in pots, the symptoms of a disease, which may be called chlorosis of sandal leaves. The symptoms of the disease are as follows. A cluster or clusters of reddish bronze cells appear on the eaten leaves either on the upper or lower surface, later becoming whitish owing to the death of cells. The clustering of cells is not regular. A white blotch may be seen at the base near the petiole, or at the apex, or at the sides of a leaf, which spreads gradually in any direction. The discoloration first appears at the point eaten by the beetles. A blotch may be present on the entire leaf on one side giving a white glistening appearance. In certain cases the eaten leaf presents a large white blotch surrounded by a bronze rim. The green tissue of the leaf, the bronze rim and the white blotch are clearly defined and distinct. The leaves become crumpled and begin to curl lengthwise over the upper or lower surface depending upon the surface mostly eaten by the beetles. The bronze cluster or white blotch, if visible on the upper surface of the leaf is not visible on the lower surface, which continues to be green at least for some time. At a later stage of the disease, the leaves begin to dry up. It has been observed that the leaves of the plants fed upon by beetles for 2½ and 5 days, have shown practically no symptoms by the first week in June. The leaves of the plant fed upon by beetles for 15 and 25 days show the symptoms of the disease markedly. The beetles in the last plant were given two extra meals on diseased

foliage during the course of the experiment and the symptoms of the disease are then manifested in a more virulent form. In one of the plants under experiment, the symptoms of the disease have been seen on a shoot which was not sleeved and remained exposed. It may further be remarked, for the present, that the beetles, were not infective for the first 7½ days, but were infective and remained infective for at least 40 days after the first 7½ days. On a healthy plant, used as control, another batch of beetles not fed on spiked plant, was allowed to feed for 25 days, and no symptoms of the disease have been observed.

Whether the symptoms now seen are the forerunners of the spike-disease of sandal cannot be said at the present stage of work, but there is no doubt that distinct symptoms of a disease have been produced by *S. cretaceus* on leaves of sandal. The sleeving experiments are intended primarily to serve as indicators and further work on this and other beetles of the family *Curculionidæ* would be concentrated under controlled conditions.

In the field, the symptoms of crumpling and curling of leaves of sandal, before and at the time the tree becomes spiked, have been confirmed. Another very important recent finding is that in spiked areas in Kottur the *Curculionid*-eaten leaves of both *Webera corymbosa* and *Canthium didymum*, are found curled as a consequence of a leaf disease, identical in both *Webera* and *Canthium*. Further search is being made and it is believed that other trees suffering from a similar disease will be found, subsequently leading to a solution of the spike-disease problem.

N. C. CHATTERJEE.

Quantitative Survey of the Insect Fauna of Sandal.

The analysis and interpretation of data provided by a roughly quanti tative survey of the insect-fauna of sandal at Aiyur and Jawalgiri, North Salem and at Fraserpet, Coorg have been carried out. This survey has been in progress since February, 1930, and was extended in December, 1930 to include sandal growing at Kottur-Yelagiri, Vellore district; the results of this extension still remain to be carefully studied.

The main object of the survey was to provide data which, when correlated with climatological information and our knowledge of the nature and characteristics of spike-disease, would indicate the selection of possible vectors for experimental and further ecological investigations. From a more

general point of view, the survey is of interest because it represents the first extended study of the fauna of a single species of tree in Indian forests. When the enquiry is concluded, it will form, therefore, a definite contribution, of economic, biologic, and taxonomic value, to the entomology of South India.

The general results of this survey and its bearing on the spike-disease problem form the subject of an illustrated paper [" Entomological Investigations on the Spike-Disease of Sandal (*Santalum album*, Linn.). 1. An Introductory Survey of the Problem "] prepared for the Conference on spike-disease of sandal held at Bangalore on June 8th. This paper provides a brief historical and ethological resumè of the disease, reviews the methods and results of the survey, discusses the complex of factors involved in the interpretation of the data, and attempts to provide a critical approach to further studies on the possible transmission of spike-disease by insects. It is assumed, as a fundamental hypothesis, that spike is a virus-disease and, as suctorial insects are primarily concerned in the transmission of such diseases, a special section is devoted to the hemipterous insects found on sandal. It is concluded that insect-transmission of spike-disease can only be effected by a specific vector, or by a small group of closely related suctorial insects. By reason of their morphology, bionomics, incidence and distribution, considered in relation to the definite but interrupted eastwards spread of the disease and prevailing wind directions in the vicinity of the localities surveyed, two out of some three hundred species of Hemiptera, *viz.*, *Tambinia verticalis* Distant (*Fulgoridæ*) and *Moonia variabilis* Distant (*Jassidæ*) are isolated as requiring immediate experimental and biological study. *Petalocephala uniformis* Distant (*Jassidæ*) and a species of *Sarima* (*Fulgoridæ*) are also thought to deserve further consideration, and attention is drawn to the possible value of observations and experiments on the *Psyllidæ*, *Aphididæ*, *Thysnoptera* and Red-Spiders (*Acarina*) found on sandal, as these groups, particularly the *Aphididæ*, are incriminated in the spread of many virus-diseases.

Of general interest is the fact that, relatively speaking, insects are not abundant on sandal, the comparative resistance of this tree to insect-attacks being attributed to the marked presence of an essential oil and the definite acidity of its sap. The phytophagous insects (specifically numerous) collected on sandal are mostly migrants from the surrounding vegetation and, though a few species breed on it, there is no indication that any species is peculiar to it or prefers it to other hosts. The insect-population of this tree is therefore essentially determined by the nature of the surrounding vegetation, lantana having a particularly obvious influence. The possibility of any insect assuming pest-proportions on sandal is also affected by the fact that parasites and predators form the most abundant biological group in the collections provided by the survey. On the other hand, defoliators,

sap-suckers and borers may be regarded as sufficiently common to have a detrimental influence on the economy of the plant, presumably reducing its resistance to spike-disease.

In the period under review my time was largely occupied, apart from routine work principally concerned with the proper maintenance and arrangement of the extensive collections, in writing various departmenta reports and the paper referred to above. The compilation of this paper was preceded by a tour (between April 5th and 28th), which not only gave me the opportunity of familiarizing myself with field-conditions and the work done by the survey-party, but also of discussing cognate problems on spike-disease with other workers, to whom I am indebted for their courtesy. This tour was a useful and essential preliminary to the presentation of the data and associated ideas obtained at Dehra Dun; it also led to extensive criticisms and suggestions for future work, which appear to have contributed to the formation of a new programme of entomlogical studies. A necessarily elaborate scheme for the determination, by specialists, of the insects collected by the survey-party has now been initiated, which it is hoped to complete during the next quarter. This work is essential to the proper progress of the enquiry undertaken by the Entomological Branch of the Forest Research Institute.

C. DOVER.

1721-31 Printed at the Bangalore Press, Mysore Road, Bangalore City.

Experiments conducted by the Madras Forest Department in co-operation with the Indian Institute of Science.

Cause.—1. Information regarding the proximity of the sites of initial attack to cultivated lands was collected and are tabulated below :—

TABLE I.

District	Places of initial attack	Proximity to cultivated fields	REMARKS
North Salem	Athinatham ..	Edge of cultivation	
	Aiyur Extension II ..	6 furlongs	Old abandoned cultivation.
	Batchecheruvu ..	By the side of a tank about 2 miles from the cultivated fields	
	Chinniguntai tank ..	1 furlong	
	Gothinatham ..	Within 2 furlongs of Gulhatti enclosure	
	Irupalnaickan tank bund	Edge of cultivation	
	Mahadeswarangudi ..	6 furlongs	
	Marandahalli ..	2 ,,	
	Nelkundi ..	2 ,,	
	Pullahalli ..	Cultivation itself	
	Royakotta spike area	On patta lands alone	
	Siddapuram unreserve	2 furlongs	
	Thalli north ..	Within 2 furlongs of Belakarai enclosure	
	Tholuwabetta spike area	Within 4 furlongs of Tholuwabetta enclosure	
North Coimbatore	Guttiyalatur R. F. ..	Within a mile of Hunsur cultivation	
	Talamalai ..	Within a mile of Mysore cultivation as well as Talamalai enclosure	
Vellore ..	Nellivasal ..	Within a mile of cultivation	
	Yelagiris ..	Cultivation itself	
South Salem	Kollimalais ..	Within a furlong	
	Pachamalais ..	Edge of cultivation	

From the above it is seen that all places of initial infection, with the exception of one particular case (Batchecheruvu), are either within a mile of cultivation or actually within cultivated areas themselves.

Data regarding the association of diseases of field crops raised in places near the sources of spike infection were collected for Manchi, Sithapuram, and Jawalagiri. In the first two, both ragi and tobacco and, in the third, only tobacco are stated to have been destroyed by some root and leaf diseases for some years both before and after spike was first observed on sandal. This appears to be a significant coincidence. More data will be collected during the next quarter and samples of affected plants will also be pressed for detailed examination.

2. *Is fire one of the contributing causes?*—The monthly incidence obtained during the period under review stands as given below:—

	PERCENTAGES		
	July	August	September
Burnt plot	4.2	2.19	1.6
Control	1.5	Nil	Nil

Nature of the Disease.—1. More figures regarding the spread of infection in various girth classes were collected for the Manchi area and tabulated. The high percentage of infection is still noted in higher girth classes alone.

Girth class, inches	Number infected	Girth class, inches	Number infected
0— 3	0	18—21	4
3— 6	0	21—24	2
6— 9	0	24—27	3
9—12	0	27—30	1
12—15	2	30—33	0
15—18	3	33—36	2
		36—39	1

2. *Grafting in higher girth classes.*—Three plots were opened in a newly spiked area at Aiyur and treated as detailed below: Plot I.—Kept as control. 15 healthy trees in one inch girth classes up to 20″ were ticketted and kept under observation. The trees that were already spiked were left untouched. Plot II.—This was treated in the same way as Plot I but the trees found infected to start with, and which might probably be the sources of infection, were removed. Plot III.—This was treated similarly to Plot II but an extra amount of infection was put in by grafting 15 trees in each of the girth classes. In each class 15 controls were marked side by side with the infected ones.

The results obtained during the quarter are tabulated below :—

TABLE II.

Percentages of spike incidence.

Girth class in inches	Plot I	Plot II	Plot III		
			GRAFTED		Control
			Fused	Not fused	
0— 1	..	..	6.6	..	..
1— 2	..	15.8	..	12.5	9.8
2— 3	..	12.5	33.3	..	2.3
3— 4	6.25	..	10.0	..	2.2
4— 5	6.6	11.8	9.1	..	13.6
5— 6	..	..	28.5	..	12.2
6— 7	..	6.6	30.0	36.4	6.9
7— 8	..	17.6	11.1	31.24	20.0
8— 9	6.25	5.9	36.4	33.3	21.4
9—10	6.25	16.6	11.1	42.9	40.0
10—11	..	10.0	20.0	40.0	60.0
11—12	..	..	33.3	50.0	40.0
12—13	..	..	33.3	25.0	33.3
13—14	7.69	..	100.0	28.5	20.0
14—15	..	..	100.0	25.0	33.3
15—16	..	10.0	..	80.0	16.6
16—17	..	16.6	50.0	40.0	40.0
17—18	20.0	16.6	100.0	..	..
18—19	..	..	100.0	33.3	25.0
19—20	..	..	..	33.3	..

It is seen that in 11 cases out of 20 the artificial infection probably in combination with natural infection gives a distinctly higher percentage. The elimination of the apparent sources of infection does not appear to be of much advantage but it is, however, too soon to judge the results. When once the infective agent is taken in, the trees in higher girth classes appear to succumb earlier than the smaller ones.

3. Attempts to induce the disease in a healthy sandal area by introducing lantana from a virulent spiked area have not been successful.

4. Monthly grafting experiments carried out in the field to determine the seasonal virulence have not yet yielded any results. The reason probably is the minimum dose of infection fixed, *i.e.*, grafting by a single leaf insertion or a patch of 0.1 sq. inch. A second set of experiments has been started by increasing the dose to double the original amount and the results are awaited.

5. Prolonged drought appears to favour the spread of infection :— The spread of spike started in 1926 in a shallow basin in the Denkanikota R.F. was confined more or less to the same limits till May last but in the

last 4 months which continued to be unusually rainless this year, the spread is considerable and the area is almost twice the original extent.

Treatments for curing the disease.—(1) The application of Atlas solution on a larger scale is postponed pending the receipt of results from laboratory experiments that are being carried out by the Institute regarding the method of its application. (2) The monthly spike incidence taken during the quarter in the limed area still confirms the results given in the last report, *i.e.*, the spread of infection is less in the locality containing a large number of host trees than in a scrub jungle with practically no tree growth. (3) The fire experiment proposed by the Working Committee as a curative treatment was not completed during the quarter as the Ranger fell sick but it is being started now.

Prevention.—(1) The plants raised under all favourable sylvicultural conditions in a limed area are now 1 year and 9 months old and are flourishing well. (2) None of the 5 year old artificially raised sandal plants treated with lime in April 1931 exhibited spike during the quarter which is very encouraging but no definite conclusions can, however, be arrived at. (3) The experiments regarding the partial deprivation of the roots of sandal is just started and no results will be available till the end of the next quarter.

Influence of host plants on the resistance of sandal to the disease.—(1) The Nyamasandiram Agraharam observation area which was abandoned is being regenerated with the favourable and unfavourable hosts. Sowings of various species have just been completed. (2) The regeneration of resistant and susceptible hosts in combination with sandal in separate plots was completed and the following species have already germinated. Sandal has come up quite well in all the plots. *Resistant.*—*Cassia siamea*, *Melia indica*, *Terminalia arjuna*, *Terminalia balerica* and *Dodonea viscosa* ; *Susceptible.*—*Pongamia glabra*, *Acacia leucophloea*, *Acacia farnesiana*, *Acacia sundra*, *Cajanus indicus*. Plants of *Terminalia balerica*, *Melia dubia*, *Zizyphus jujuba*, transplanted in resistant host plots are also coming up well. (3) The following species have been transplanted with sandal in plots under controlled conditions and grafting will be undertaken when sandal grows to a decent size.—*Vitex pubescens*, *Cedrela toona*, *Chloroxylon swietenia*, *Dodonea viscosa*, *Semecarpus anacardium*, *Albizzia amara*, *Dichrostachys cinerea*, *Holoptelia integrifolia*, *Opuntia dillenii*, *Physalis minima*, *Holarrhena antidysentrica*, *Grewia orientalis*, *Balanites Roxburghii*, *Leonotis neptaefolia*, *Grevellia robusta*, *Calotropis gigantea*, *Crinum asiaticum*, *Cassia laevigata*, *Celastrus paniculata*, *Cassia montona*, *Cassia auriculata*, *Cassia fistula*, *Cassia siamea*, *Ocimum canum*, *Ocimum sanctum*, *Sansvera zelanica*, *Vitis quadrangularis*, *Feronia elephantum*, *Ricinus communis*, *Bauhinia racemosa*, *Scutia indica*, *Acacia ferruginea*, *Pithecolobium saman*, *Pithecolobium dulce*, *Chukrasia tabularis*, *Melia dubia*, *Toddalia aculeata*, *Zizyphus jujuba*, *Poinciana regia*, *Ruta graveolens*, *Erythrina indica*, *Terminalia arjuna*, *Kalanchœ floribunda*, *Dalbergia latifolia*, *Pittosporum floribundum*,

Bassia latifolia, *Schleichere trijuga*, *Stephegyne parvifolia*, *Tectona grandis*, *Albizzia odoratissima*, *Casuarina equisitifolia*, *Ocimum basilicum*, *Melia azidirach*, *Nicotiana tabacum*, *Argyriea cuneata*, *Melia indica*, *Acacia concinna*, *Solanum seaforthianus*, *Murraya kœniigii*, *Murraya exotica*, *Adenanthera pavonina*, *Mundolia suberosa*, *Capsicum frutescens*, *Atlantia monophylla*, *Anogeissus latifolia*, *Achyranthus aspera*, *Cudrania javanensis*, *Acacia intsia*, *Acacia farnesiana*, *Thevetia nerifolia*, *Artocarpus integrifolia*, *Terminalia balerica*, *Psidium guyava*, *Webera corymbosa*, *Prosopis juliflora*, *Cordia myxa*, *Acacia sundra*, *Erythroxylon monogynum*, *Gmelina arborea*, *Flacourtia sepiaria*, *Strychnos potatorum*, *Opilia amentacea*, *Acacia arabica*, *Albizzia lebbek*, *Anisochilus carnosum*, *Acacia suma*, *Pongamia glabra*, *Strychnos nux-vomica*, Lantana, Bamboos, *Cajanus indicus*, *Jatropha curcas*, *Zizyphus œnoplia*, *Aristolosia indica* and *Amarantus gangeticus*.

(4) Sandal plants raised with *Pongamia glabra*, *Acacia farnesiana*, Lantana, *Zizyphus œnoplia*, *Strychnos nux-vomica* and *Dendrocalamus strictus* in pots were 2 years old by September 1931 and were sufficiently thick and high. 10 of each of these plants have now been grafted by leaf insertion and results are awaited.

The above experiment has been extended to the field where instead of pots, big earthen mounds have been raised and regenerated with the following species both individually and in combination with sandal. These are not yet fit for grafting purposes. (i) Species raised individually on mounds.—*Acacia farnesiana*, *Casuarina equisetifolia*, *Zizyphus œnoplia*, *Divi Divi*, lantana, *Melia indica*, *Albizzia amara*, *Phyllanthus emblica*, *Dodonea viscosa*, *Scutia indica*, *Pongamia glabra*, *Ficus glomerata*, *Cajanus indicus*, *Dalbergia sissoo*, *Semecarpus anacardium*, *Strychnos nux-vomica*, *Cassia siamea*, *Murraya kœniigii*, *Chloroxylon sweitenia*, *Eugenia jambolana*, Bamboo, *Feronia elephantum*, *Terminalia arjuna*, *Zizyphus jujuba*, *Aristolochia indica*, *Anogeissus latifolia*, *Toddalia aculeata*, *Acacia intsia*, *Pittosporum floribundum*, *Mundolia suberosa*, *Albizzia lebbek*, *Melia azidirach*, *Pithecolobium saman*, *Pithecolobium dulce*, *Cassia fistula*, *Acacia suma*, *Thevetia nerifolia*, *Albizzia odoratissima*, *Webera corymbosa*. (ii) Species raised in combination on mounds.—*Mundolia suberosa* and *Melia indica*; *Pongamia glabra*, lantana and *Acacia intsia*; *Melia indica* and *Cassia siamea*; *Cassia siamea* and *Pithecolobium dulce*; *Pongamia glabra* and *Semecarpus anacardium*; *Cassia siamea* and *Zizyphus jujuba*; *Chloroxylon swietenia* and *Melia indica*; *Cajanus indicus*, lantana and *Acacia suma*; *Acacia farnesiana* and *Pongamia glabra*; *Murraya kœniigii*, *Cassia siamea* and *Melia indica*; *Acacia suma* and lantana; *Pongamia glabra*, lantana and *Acacia intsia*; *Albizzia amara* and *Cassia siamea*; *Pongamia glabra*, lantana and *Acacia suma*; *Cassia siamea*, *Murraya kœniigii* and *Melia azidirach*; *Cassia*, *siamea* and *Terminalia arjuna*; *Albizzia amara* and *Semecarpus anacardium*; *Cajanus indicus*, *Pongamia glabra* and *Acacia suma*; *Cajanus indicus*, *Pongamia glabra*, *Acacia suma* and lantana; and *Cajanus indicus*, *Zizyphus jujuba* and *Cassia siamea*.

(5) Sandal plants in association with *Feronia elephantum* have been grafted twice, but on both the occasions the fusion did not take place and the patches put in were found to be thrown out by callus formation.

(6) The sandal trees which escaped infection in the Mahadeswarangudi observation area were presumed to be resistant and some of these artificial infections were tried twice and on both these occasions the patches have been resisted. Some of the plants which have grown in the area since 1916 were also infected but only one of these has succumbed.

Is timber or fuel exploitation associated with the primary sites of infection ?— Ecological surveys, so far, conducted in collaboration with the Institute have established the fact that spiked trees were almost always associated with a large number of dead stumps. The experiments proposed to verify this statement and also to determine the influence of hosts, in general, on the resistance of sandal plants to infection have been started in the Noganur R.F. and are in progress.

Other experiments.—The conversion of the Jawalagiri manurial experimental area into experimental plots for raising the resistant varieties of sandal has also been completed.

The results of ecological survey carried out on the Yelagiris were tabulated and found to coincide with the results already published (*J. Indian Inst. Sci.*, 1931, **14A,** 59).

J. E. M. MITCHELL.
S. RANGASWAMY.

Coorg Experiments.

1. **Direction of the spread of the disease.**—Recent observations in the Somwarpet Range would appear to indicate that the disease travels in a north-easterly direction and confining itself to the Coorg-Mysore frontier. In 1928, a village called Doddare was found to be infected. In 1929 a few spiked trees were found at Hosaguthi, which is approximately one mile norh-east of Doddare. In the same year, one spiked tree was found in the 1894 Kargode plantation and two more in the Genibetta Reserve, which localities are a mile and a half from and more or less north of Hosaguthi. All these areas are infested with lantana.

Observations in the Fraserpet Range, however, show that the direction of spread has, for the last two years, been towards the south. During extraction work in August this year, infected trees were found in Kattemadu village, which hitherto was not infected, and lies at a distance of three to four miles south of Cherala-Srimangala, the nearest infected area.

2. **Incidence of spike in relation to lantana.**—There are records to show that lantana appears to have been introduced into Coorg in the late "fifties"—the first official mention of it was in 1877, whereas Mr. McCarthy first reported in 1899, *i.e.*, at least 22 years and probably 40 years later.

Removal of lantana *may* reduce the incidence of spike, but lantana was removed from the Fraserpet plantations, shortly before 1912. These plantations are now hopelessly spiked.

3. Within the last 3 years fresh attacks have been recorded in the Hosaguthi village, the 1894 Kargode plantation and in the Gonibetta Reserve of the Somwarpet Range. In August this year infected trees were found at Kattemadu village of Fraserpet Range.

It is now reported that of the 36 sandal trees in the Hunsur Depot, one, which is associated with *Cassia siamea* as a host, has been attacked by spike.

There are now spiked trees outside the Depot within 10 feet of sandal so far remaining unattacked in the Depot.

4. A detailed list of host plants associated with sandal in the Hunsur Depot is given in Table I.

TABLE I.

List of sandal trees in Hunsur Depot, showing (*a*) the condition of each tree and (*b*) the nature of its hosts on 23-7-1931.

Tree No.	Condition	Hosts
1	Healthy, but growing on rocky soil.	(*a*) *Cassia siamea.* (*b*) Toddy palm
2	Twigs dead, lower branches healthy and green.	(*a*) *Albizzia amara.* (*b*) Common aloe.
3	Do.	Do.
4	Stem partially dead, branches healthy.	(*a*) Yellow flowered leguminous hedge plant. (*b*) *Zizyphus œnoplia.*
5	Healthy.	Do.
6	Healthy, but a few branches with smaller leaves.	Do.
7	Healthy, but terminal twigs dead.	(*a*) Yellow flowered leguminous hedge plant. (*b*) Lantana. (*c*) Common aloe. (*d*) *Jatropha curcas.*
8	Do.	Do.

Tree No.	Condition	Hosts
9	Healthy, but terminal twigs dead.	(*a*) Yellow flowered leguminous hedge plant. (*b*) *Zizyphus œnoplia.* (*c*) Solanum creeper.
10	Very healthy.	Do. also (*d*) *Albizzia amara.* (*e*) *Melia indica.*
11	Do.	Do.
12	Healthy.	Do. also (*f*) *Butea frondosa.*
13	Do.	(*a*) Yellow flowered leguminous hedge plant. (*b*) Purple flowered solanum climber. (*c*) *Butea frondosa.*
14	Healthy, but a young plant only about $2\frac{1}{2}'$ high.	Do.
15	Healthy, but terminal twigs dead.	(*a*) *Albizzia amara.* (*b*) Lantana. (*c*) Common aloe. (*d*) *Cassia siamea.* (*e*) *Euphorbia* spp. (*f*) Solanum creeper.
16	With many dead twigs, but leaves apparently healthy.	(*a*) *Zizyphus œnoplia.* (*b*) Common aloe.
17	A very healthy tree with leaves much elongated.	*Dalbergia paniculata.*
18	Healthy, but terminal twigs dead.	(*a*) Do. also (*b*) Lantana. (*c*) *Zizyphus œnoplia.*
19	Healthy, but terminal twigs dead.	(*a*) Lantana. (*b*) *Jatropha curcas.*
20	Very healthy.	(*a*) *Cassia siamea.* (*b*) Aloe. (*c*) Ficus species.

Tree No.	Condition	Hosts
21	Healthy. It was very unhealthy looking about three years ago, but has revived marvellously as a result of accidental shaking and probable consequent æration of root system.	(*a*) *Anona squamosa.* (*b*) Jasmina climber. (*c*) A common perennial garden plant known as "Dead man's flower".
22	Quite healthy.	*Cassia siamea* only.
23	Healthy, a young plant about 2½′ high.	Do.
24	Healthy, a young plant about 6′ high.	Do.
25	Quite healthy, with a number of young seedlings under it.	Do.
26	Very healthy.	Growing in isolation. Nearest host *Cassia siamea* about 30′ away.
27	Unhealthy looking, leaves yellowish	(*a*) *Adina cardifolia.* (*b*) *Cassia siamea.*
28.	Quite healthy, with full crown and seedlings under it.	Growing in isolation. Nearest host *Cassia siamea* about 25′ away.
29	Healthy.	(*a*) *Cassia siamea.* (*b*) *Butea frondosa.*
30	Do.	*Cassia siamea* only.
31	Very healthy, a young plant about 10′ high.	(*a*) *Cassia siamea.* (*b*) Lantana.
32	Very healthy, a young plant about 5′ high.	(*a*) Yellow flowered leguminous hedge plant. (*b*) Solanum creeper.
33	Spiked, situated behind motor shed. A root sucker of this tree about 18′ away is also spiked.	*Cassia siamea* only.
34	Very healthy, and about 16′ away from tree No. 33, which is spiked, and growing under apparently identical conditions.	Do.

Tree No.	Condition	Hosts
35	Branchlets dead, otherwise healthy, growing on rocky soil.	(*a*) *Albizzia amara.* (*b*) *Jatropha curcas.* (*c*) Yellow flowered leguminous hedge plant. (*d*) Common aloe.
36	Branchlets dead, otherwise healthy, growing on rocky soil, close to tree No. 35.	Do.

H. A. H. G. HICKS.

A. R. BRAND.

Experiments conducted by the Indian Institute of Science—I.

Field Experiments.—1. *Manurial and Regeneration Plots.*—(i) The Jawalagiri manurial plot has been converted into a regeneration area where varieties of sandal, experimentally found to be disease-resistant are being introduced. The necessary control plots have been laid. Hosts found to impart relative immunity to sandal, are also being introduced into the area. Ecological changes, brought about by these operations, are being closely recorded by the periodic studies of the area. (ii) The same experiment is being repeated in the Nyamasandiram observation area at Aiyur. (iii) Detailed observations are being continued in the manurial plots at Aiyur, with special reference to the study of individual sandal plants in relation to their associated hosts. (iv) Sowings and plantings in the Regeneration plots at Jawalagiri are completed. The germination of sandal has been quite encouraging. (v) Mound planting at Jawalagiri is also complete and the plants have established themselves sufficiently to withstand the next period of drought.

2. *Grafting under sylvicultural conditions.*—(1) Results of grafting on trees of various girth classes in the Samayeri plots, are tabulated below :—

TABLE I.

Plot	No. of plants under observation	No. of plants spiked during June-Sept.	Percentage of incidence
I. Control, spike left ..	233	6	2.6
II. ,, spike removed ..	251	19	7.5
III. (*a*) Operated stocks ..	299	80	27.0
(*b*) Controls ..	440	73	17.5

It will be seen that disease-incidence in plot III among operated stocks is 10 per cent. higher than among the controls interspersed among them. The comparatively high percentage of incidence even among the unoperated controls, shows that the spread due to natural causes is very high and throws considerable doubt on the resultant effect of introducing more infection in the way of grafting. Further, disease incidence in plot III is higher than that obtaining in either of the two other plots I and II which have, therefore, not served as strict controls to the experiment. In fact, the percentage of incidence steadily decreases as we go towards plot I beyond which, lies the healthy area. It would be instructive to determine the relative abundance of insect fauna in these plots. A study of the floristic composition of these plots is comtemplated.

Table II shows the percentage of success obtained by patch-grafting as determined by the effective organic fusions and also the incidence among various groups. Similar results for the Mahadeswarangudi area are included in the same table.

TABLE II.

Area	No. of plants operated	Operations successful	Percentage of success	Percentage of incidence among		
				Successful	Unsuccessful	Unoperated controls
Samayeri ..	299	128	43.6	23.4	29.2	16.5
Mahadeswarangudi	40	30	75.0	3.3	0.0	0.0

The incidence due to natural factors in Samayeri is so high that the results cannot be usefully interpreted. But the results of grafting operations at Mahadeswarangudi have established the comparative resistance exhibited by the sandal plants to artificial grafts. The different type of floristic aspect presented by the area is, no doubt, responsible for this encouraging result. The area has not degenerated into the scrub type; there is an abundance of

deep-rooted hosts as compared with the number of parasitic sandal plants stocked in the area; and if scars inflicted on sandal could be taken as a measure of insect abundance, the Mahadeswarangudi area harbours very much less number of insects. Per 100 feet of green sandal twigs examined, Samayeri area has 1,408 scars as compared with 29 small ones for the Mahadeswarangudi area.

3. *Grafting of sandal plants growing in association with special types of host plants.*—In the Nyamasandiram Agraharam observation area, there are a few sandal plants growing around a big *Feronia elephantum.* These plants were repeatedly grafted both by the leaf insertion and bark patch methods. The plants have not succumbed to the disease although the control plants associated with an *Acacia leucophlia* on grafting, have got spiked. Unfortunately, this interesting fact is not supported by other field observations where under natural conditions several sandal plants apparently in association with *Feronia* have got spiked. A more detailed study of this question is, however, necessary before any definite conclusions could be drawn. Experiments under controlled conditions in pots have also been initiated.

Ecological aspects of the problem of spike-disease.—In a recent paper on "Ecology of Sandal", (*J. Indian Inst, Sci.*, **14A,** 59-65), attention is called to the frequent association of agricultural fields with the primary sides of attack. In the case of every one of the diseased areas so far investigated there has not been a single exception. If this statement is further substantiated by an extended enquiry now in progress, it would open up a fruitful line of research. Information so far collected by personal inspection and enquiry is tabulated below:—

TABLE III.

Primary sites of infection in relation to agricultural fields.

Locality	Description of the site	Distance from the nearest field	REMARKS
Jawalagiri	On a tank bund	1 furlong	Was a resting place for the cattle of the village; thick lantana growth.
Uduparani	In the unreserve close to the village	Less than a furlong	Heavy grazing and exploitation of fuel and timber. Thick lantana growth. Frequent fires.
Manchi	A slight slope	Edge of cultivation itself	Heavy grazing, frequent fires and exploitation of timber.

Locality	Description of the site	Distance from the nearest field	REMARKS
Nognoor	Slope with soil erosion	Within a furlong	Heavy grazing and fuel exploitation.
Guttiroyans	The top of the hill	Edge of cultivation	Close to the huts of wild tribes. Frequent fires and heavy exploitation of timber.
Fraserpet	Agricultural fields all round	Edge of cultivation	Exploitation of timber; fires and thick lantana growth.
Hunsur	Gentle rocky slope	Edge of cultivation	Severe forest fires and grazing.
Hulyurdurga	Rocky soil	Edge of cultivation	Fuel exploitation.
Uttarahalli	Right in the midst of garden cultivation		Mainly fed by *Pongamia glabra* hosts on the bunds.
Ragihalli	Slope of a rocky hill, by the side of a frequent foot-path	2 furlongs	Severe forest fires; heavy grazing and exploitation of fuel.
Savandoorg	Rocky soil	2 furlongs	Exploitation of fuel and forest fires.
Closepet	Rocky soil	1 furlong	Fuel exploitation and forest fires.
Narayandoorg	Hillock	2 furlongs	Fuel exploitation and grazing.
Hirehalli	Rocky soil	2 furlongs	Fuel exploitation and grazing.
Denkanikota		1 furlong	

Table III shows that practically all areas have suffered from fuel exploitation, grazing and often forest fires leading to a secondary succession of vegetation. Rao Sahib Venkataramana Ayyar's remarks in reply to an enquiry in this connection, are noteworthy. "But it is the case that sandalwood is confined to fringes in and round enclosures within reserved forests and as such every infection must have been in the neighbourhood of cultivations. It is not possible, however, to state whether, at the time of the primary attack at any one place, the agricultural crops in the neighbourhood suffered from any disease, because observations under this head have seldom been recorded. But there is one significant factor present in nearly every case of spike attack that I have known, and that is that the disease starts—may be in the

neighbourhood of cultivations—in an area of forest where original climax forest cover has undergone a change and secondary successional stages of vegetation have come to be established in its place, which differs either floristically or as regards growth, form, vigour and the nature of the shrub and ground flora layers, from the original stand (climax forest) on the same area. That such deterioration of climax forests can take place almost always in the neighbourhood of cultivations or alongside public roads passing through such forests is conceivable. In fact, the absence of the primary climax type and the presence of the secondary successional type of low scrub and bushes amidst which alone spike incidence is the heaviest are a common feature in nearly all spike infected localities that I have known."

It is, therefore, clear that the secondary succession of vegetation brought about by various types of denudation predisposes the sandal plants in the area to spike disease. But the ultimate source of the causal entity is yet unknown. It is yet to be determined if the causal entity is borne by (1) any of the new species invading the denuded area, or (2) through the agricultural crops raised nearby.

If the degeneration of climax forests is accepted as the predisposing cause of the disease, a reversal or the restoration of the forest to the original type should constitute the ideal method of combating the disease. Field experiments in this direction have already been initiated. Rao Sahib Venkataramana Ayyar significantly remarks, "that the healthy future of our natural sandal areas probably lies in restoring the localities to their original climax types by planting some hardier and deep-rooted species from severer localities of the same country." In my contribution on the "Ecology of Sandal" I have tried to emphasize the same point of view by pointing out that the successful and practical solution to the problem of spike disease consists in a judicious choice of host plants having regard to the environmental factors under consideration. A separate note on this important aspect, which is being prepared, will shortly be published.

Laboratory Experiments.—1. *Sap injection versus Tissue transplantation.*
2. *Experimental transmissions of the disease.*

Further attempts at inducing the disease by the following methods have proved unsuccessful :—(*a*) soaking healthy tissues of sandal (leaf and bark) in the tissue fluids of a spiked plant and grafting them on to healthy stocks. (*b*) Kaolin and talc were used to adsorb the infective agent from the diseased leaf-tissue fluids. The adsorbate was eluted with phosphate buffer (p_H 4.5) and the elutant was used for infecting the healthy stocks. The residual liquid after treatment with adsorbant as also the original liquid were used for infecting separate sets of healthy stocks. In no case has there been a transmission. (*c*) Electro-dialysed infective tissue fluids also have not been successful in transmitting the disease. On the other hand, the following methods of transmission have met with success :—(*a*) Scratching several times a healthy

stock with a small serrated knife alternately employed for scratching a spiked plant to ensure carriage of infective tissue. (*b*) Small, tiny fibres from the bark of a diseased plant transplanted on healthy stocks by making very small incisions.

3. *Transmission in relation to hosts.*—Comparative immunity to artificial grafts is exhibited by sandal plants growing in association with *Terminalia arjuna* while those fed by *Ocimum sanctum* are rendered particularly susceptible. These experiments are being extended to all species of hosts characteristic of sandal areas.

4. *Transmission in relation to special soil constituents.*—Groups of sandal plants in association with *Acacia farnesiana* have been manured with (1) calcium arsenate, (2) calcium borate, (3) manganese and (4) sulphur. Analysis of the tissues of sandal has revealed the presence of arsenic and boron respectively in estimable quantities. Analytical data with regard to (3) and (4) are not yet available.

5. *Experiments on ringing.*—Experiments on ringing have shown (1) that if the ring is made below the point of infection, the virus does not affect portions below the ring, (2) that the infective principle is transported largely through the bast and cortex and (3) that, on ringing, portion above the ring gets spiked and dies much earlier than it would otherwise. There observations explain the erratic way in which spike appears and progresses on individual trees under natural conditions.

M. SREENIVASAYA.

Experiments conducted by the Indian Institute of Science—II.

Field work.—Reconnoitring surveys were made of the Siddapuram area and the Manchi Reserve. The growth of sandal in both the cases was good, particularly so in the latter. The appearance of spike could not in either case be traced to any definite visible factor. In both localities other species exhibiting spike-like symptoms were also found.

Biometric measurements.—In continuation of what has already been stated in the last report, further data were collected for sandal leaves from various localities and in association with different host plants. The results have been presented in the following table :—

TABLE I.

Locality	Condition of the plants	$\frac{L-P}{B}$	P. in mm.	Range in internodal distance	REMARKS
Bangalore ..	Healthy	2.2	11.3	16.5—29	Specimens from round near Bangalore.
,, ..	Spiked	4.1	2.55	3.5— 9.8	Do.
Nognoor ..	Healthy	2.2	8.3	11 —23	Healthy in a spiked area.
,, ..	Spiked	3.6	3.0	4 — 6	..
,, ..	Suspected to be spiked	2.75	5.0	1 —30	The plant has been flowering and fruiting.
Denkanikota ..	Healthy	2.40	10.0	4 —12	Attacked by insects.
Fraserpet ..	Healthy	2.4	10.0	..	..
,, ..	Suspected	2.5	6.25	..	The measurements show that the plant is healthy.
,, ..	,,	2.42	7.0	..	

Chemical analyses were carried out to test the conclusions reached from the biometric measurements and were found to be in general agreement with them.

The suspected plants from Fraserpet were originally supposed to represent a flowering type of spike. The inference drawn from biometric measurements was subsequently supported by observations on later collections of leaves which came out perfectly healthy.

Experiments in connection with the eradication of spike.—In an attempt to eradicate spike, the Madras Forest Department tried various treatments including the application of the patented tree-killer, Atlas Solution. In the last case, the treatment consisted in girdling the affected branch of a partially spiked tree and smearing the exposed wood with the above solution. It was found that in many cases as a result of the treatment the diseased branch was killed while the others continued to remain, at least apparently, healthy.

Definite information with regard to the efficacy of the treatment as a means of eradicating spike is, however, lacking. (*Vide* the author's contribution to the Proceedings of the Fifth Spike Conference, *Indian Forester*, May 1931). The experiments were repeated in 1929 and 1931 but the results were not consistent. In some cases the solution did not act at all. In some others, apparently healthy parts developed the symptoms of the disease,

The experiments that were carried out in January 1931, led to some unexpected findings. In one case epicormic shoots were observed below the treated portions, while those above were quite dead. It was also noticed that proximity of the treated parts to the roots influenced the effect considerably.

The foregoing and other observations suggested that a systematic study of the mode of action of Atlas Solution would lead to useful findings. An extended investigation on the efficacy of treatment with Atlas Solution and certain other tree-killers has, therefore, been undertaken.

In view of its poisonous nature, it was considered to be essential to determine whether any of the arsenic present in Atlas Solution passed into the essential oil obtained from Atlas treated trees. With this in view sandalwood oil was extracted from spiked trees treated with Atlas and tested for arsenic. In the cases studied till now no arsenic could be detected.

The virus nature of spike.—In view of the opinion generally held that spike disease is of the virus type, some experiments were carried out to determine the nature and trace the progress of the X-body. Although specimens of diseased leaf tissues from various localities have been examined, it has not, so far, been possible to detect the presence of any foreign body. Further study is in progress.

Examination of leaves to which a disease had been communicated by *Sympiezomias cretaceous* beetles.—In the previous report (p. 13) mention was made of the communication of a disease by *Sympiezomias cretaceous* beetle from spiked to healthy sandal. In view of the possibility of the symptoms of the disease being the precursors of the spike, specimens of the diseased leaf tissues were chemically analysed to ascertain whether they showed any of the abnormalities generally associated with the latter disease.

	Percentages on dry weight		
	Suspected specimens	Typical healthy	Typical spiked
Total ash ..	13.70	13.65	8.65
Nitrogen ..	4.04	2.88	3.29
Lime (CaO) ..	3.62	3.44	1.20
Calcium/Nitrogen (Ca/N) ..	0.64	0.85	0.26

The increased amount of nitrogen in the leaves cannot be easily accounted for, but various factors such as hosts, age, effect of the insect feed, etc., have to be taken into consideration. The other data correspond to those of the healthy plants. Moreover, the ratio of calcium to nitrogen is much higher than that of the diseased one. Microscopical examination

did not reveal the accumulation of starch in the leaves as is usual with diseased sandal. Biometric data for the suspected specimens were not significantly different from those of healthy ones. Histological examination is in progress.

A. V. VARADARAJA IYENGAR.

Experiments conducted by the Indian Institute of Science—III.

Distribution of hexone bases in the leaves of healthy and spiked sandal.—In a previous publication (*J. Indian Inst. Sci.*, 1929, **12A**, Pt. X) Sreenivasaya and Narasimhamurthy showed that the water soluble and basic nitrogen were present in greater amounts in the leaf-tissues of spiked sandal than in that of the healthy one.

In view of the above, it was considered desirable to make a systematic study of the hexone bases present in the leaves of healthy and spiked sandal respectively with a view to determine the nature of the metabolic disturbances which manifest themselves with the onset of the disease. The chemical analyses were carried out by two different methods.—(1) Van Slyke's method as modified by Plimmer and Rosedale and (2) Kossel's method.

The results have been presented in the following table :—

	Percentage of total basic nitrogen	
	Healthy	Spiked
Arginine	66.48	25·91
Histidine	3·60	43·84
Cystine	16·37	6·34
Lysine	13·42	23·69

It may be noted that the histidine fraction in the spiked leaf is very much greater than in the healthy one, while cystine is present in larger quantities in the healthy one than in the spiked. The occurrence of histidine in such large quantities in the spiked leaf-tissue is rather significant in view of its close relationship to the physiologically active histamine which is known to inhibit the development and active functioning of the roots.

Why is the diseased leaf-tissue richer in nitrogen than the healthy one?—It has been observed by several workers that the diseased leaf-tissues

contained invariably a higher percentage of nitrogen than the corresponding healthy one. There are two possible methods by which such a transformation could occur:—(1) Translocation of nitrogen to the leaves from the other parts of the spiked sandal, and (2) presence of nitrogen fixing bacteria.

Experiments were conducted to determine whether nitrogen fixing organisms were present attached to the diseased leaves as distinct from the healthy ones. The results show that no significant difference with regard to the flora or their nitrogen fixing ability could be observed.

Y. V. SREENIVASA RAO.

Entomological Investigations by the Forest Research Institute: Work done at Dehra Dun.

The project for the specific determination (see last quarterly report, page 16) of the five lakhs or so of insects collected on sandal has been practically completed in so far as work at Dehra Dun is concerned. A representative selection (totalling some eight thousand specimens) of species belonging to forty groups has been sent to nearly twenty-five specialists in India and abroad. The routine labour involved in this work has been very considerable, and it has only been possible to undertake it by utilizing the resources of the section of Systematic Entomology. Messrs. G. D. Bhasin, G. D. Pant and M. Bose, Assistants in this section, have rendered enthusiastic service in this connection.

The anticipated returns are a series of reports that will represent the first taxonomic study of the insect-fauna of a single species of tree in Indian forests and form an unique contribution, of both economic and academic interest, to Indian entomology. These reports will provide the basis for a final analytical study of the insect-fauna of sandal and its bearing on spike-disease. The importance of a sound systematic foundation in work of this kind cannot be too strongly emphasized, for the correct identification of an insect is the key to all that is known about it. And such knowledge is essential for the proper consideration of the problems before us.

Chief among the specialists to whom we are indebted for assistance is Sir Guy Marshall, Director of the Imperial Institute of Entomology. He has not only undertaken to report on the very extensive collection of weevils (*Curculionidæ*), but has also arranged for the determination of several important groups of insects (*Chrysomelidæ*, *Fulgoridæ*, *Pentatomidæ*, parasitic *Hymenoptera*, etc.) by spcialists associated with his Institute. Our project could not have been completed without Sir Guy Marshall's assistance.

The other specialists who are co-operating with us and to whom collections have been sent are: Dr. L. Chopard, Paris (all *Orthoptera*); Dr. Nathan Banks, Massachussets (all *Neuroptera*); Mons F. Lallemand, Uccle, Belgium (*Cercopidæ*); Mr. F. Laing, London (*Psyllidæ*); Mr. H. E. Andrews, London (*Carabidas*); Dr. W. Horn, Berlin (*Cicindelidæ*); Mons A. Thery, Robat, Morocco (*Buprestidæ*); Mons E. Fleutiaux, Paris (*Elateridæ, Melasidæ*); Dr. J. B. Corporaal, Amsterdam (*Cleridæ*); Dr. R. Kleine, Stettin (*Lycidæ, Brenthidæ*); Dr. F. von Emden, Dresden (*Rhipiceridæ*); Mr. K. G. Blair, London (all *Heteromera*); Dr. R. Heberdey, Graz, Austria (*Anthicidæ*); Mr. G. J. Arrow, London (*Scarabeidæ, Erotylidæ, Endomychidæ, Languridæ*); Mr. F. W. Edwards, London (*Diptera*); Dr. R. Korschevsky, Berlin (*Coccinellidæ*); Dr. W. D. Funkhouser, Kentucky (*Membracidæ*); Dr. H. S. Pruthi, Calcutta (*Jassidæ*); Mr. D. Mukerjee, Calcutta (*Formicidæ*); Dr. T. V. R. Ayyar, Coimbatore (*Coccidæ, Thysanoptera*).

Arrangements have also been made for the identification of spiders by Dr. W. Rae Sheriffs of Sheffield University and of wood-lice by Dr. B. Chopra of the Indian Museum, Calcutta. Dr. Baini Prashad has identified the molluscs.

We have also endeavoured to establish relations with prominent workers on virus-diseases to obtain their opinion on our work and to keep ourselves acquainted with the latest developments in virological research. In research such relations are always productive. For example, the following extract from a letter to the Forest Entomologist by Dr. H. H. Storey, the well-known Plant Pathologist of the East African Agricultural Research Station at Amani, Tanganyika, has a particular significance in view of certain statements made in the last quarterly report: "It appears to be accepted by some of your colleagues that the failure of attempts at inoculation with sap constitutes a proof that insects are not involved in the transmission of the virus disease concerned. My own experience entirely contradicts this. Many virus diseases, known to have specific insect vectors (including streak of maize and groundnut rosette), have resisted all attempts at infection by mechanical inoculation of sap.

"I personally hold the view that every plant virus will eventually be found to have an insect vector. On the other hand, *every* plant virus may be transmitted by tissue-transplantation *provided organic union takes place.* The fact that sandal spike is so transmitted does not place it in a different class from other virus diseases." This opinion provides encouraging support for the arguments (so strongly contested by Mr. Sreenivasaya) put forward by myself on more than one occasion.

It is expected that the quarter now in progress will be largely devoted to the disposal of the remaining collections and the preparation of results for publication.

CEDRIC DOVER.

2652-31 Printed at the Bangalore Press, Mysore Road, Bangalore City.

Experiments conducted by the Madras Forest Department in collaboration with the Indian Institute of Science.

Is fire one of the predisposing causes?—Disease incidence data of the fire plots during the period under review are given in Table I.

TABLE I.

	Percentages			Total period, 8 months
	October	November	December	
Burnt plot	0.0	0.9	1.9	16.9
Control	0.9	1.3	1.1	11.8

Percentage of disease incidence during this quarter in both the plots is distinctly lower than that for the last quarter and taking the whole period, since commencement, into consideration, burnt plots reveal significant increase in incidence. This increase is largely due to the effect of fire on the sandal plant in stimulating the growth of secondary dormant buds which provide an ideal medium for the manifestation of disease. Pollarding has the same effect as fire, in so far as the operation leads to the forcing out of the dormant buds into new flush. Any factor either artificially inflicted or naturally inevitable, like season, which encourages the growth of young tissue, may, in general, be taken to favour the external manifestation of disease symptoms in an infected plant. Observations both in the manurial plots and other observation areas in N. Salem and Coorg lend support to this view because the period of maximum incidence synchronizes with the period of new growth under sylvicultural conditions.

It should be emphasized that fire in the present instance is only an accelerating cause and not a predisposing factor since these experiments have been conducted in a heavily spiked area where one expects to find a large number of sandal plants harbouring the infective principle.

The rôle of fire as a predisposing factor is a subject of considerable practical importance. "Fire" experiments in a healthy area have not resulted in any manifestation of disease but, on the other hand, it has brought about a complete change in the ecological make up of the area. Fire is universally

recognized to be a powerful denuding factor influencing rapid ecological succession and this aspect of the question has a fundamental bearing upon the problem of spike-disease.

Lantana in relation to spike-disease.—Frequent forest fires open out the forest giving place to inferior species like lantana whose aggressive invasion has almost always preceded the incidence of spike-disease in any particular area. Reference has been made to this fact in a recent communication titled "Ecology of Sandal" (*J. Indian Inst. Sci.*, 1931, **14A,** 59) where it has been shown that the abundance of lantana in a spiked area is fifteen times as much as what usually obtains in a corresponding healthy area. The rôle of lantana in predisposing sandal areas to disease is manifold :—(1) its aggressive and rapid spread suppresses the growth of comparatively slow-growing and deep-rooted species which may be of considerable host value to sandal; (2) owing to its comparatively shallow root system and its being one of the earliest to shed leaves with the approach of drought, lantana does not provide the sandal parasitic on it with a continuous and unfailing supply of nutrition; (3) lantana is easily susceptible to fires, especially during the hot weather, and thus contributes towards a greater frequency of fires in the area leading to a gradual annihilation of all the species useful to sandal. A few areas in Jawalgiri, in fact, represent practically a pure patch of lantana with a few *Acacias* and sandal plants struggling in their midst; (4) insects are found to increase in lantana-infested areas in both variety and abundance; (5) bird-life which would tend to restrict an abundance of insect fauna, is scarce in lantana-infested areas, as the areas become unattractive to birds due (*a*) to scarcity of food and (*b*) to danger from fires; and (6) the toxicity imparted to the soil by lantana growth affects the growth of other plants in the area. Plants (sandal and *Acacia farnesiana*) grown in pots, on soil derived from lantana-infested areas, did not thrive well. A large percentage of them have already died, while the others are just struggling for existence.

It has been found that keeping down lantana artificially has a marked effect in reducing the incidence of disease, as found in Cairn No. 53 Observation area. This fact is due to the circumstance that continual weeding out of lantana has enabled other beneficial species to come up. A comparative study of the plots, (A) lantana-infested (control) and (B) lantana free with regard to floristic composition, has revealed very significant differences. The change that one observes to-day in the two plots is one that has been brought about during the last seven years, a sufficiently long period for the establishment of a marked and visible ecological succession. Weeding out of lantana in plot (B) has been the only operation carried out. There have been no fires during the whole period. The plots, therefore, represent the most valuable sites from the point of view of a study of the ecological change that occurs by keeping down lantana. Table II gives the results

TABLE II.

Results of ecological survey in Cairn No. 53 Observation area plots.

		Lantana-free	Lantana-infested
Acanthaceæ	*Barleria buxifolia*	2	0
,,	*Strobilanthus* sp.	59	2
Apocynaceæ	*Carissa paucinervia*	14	0
Bixaceæ	*Flacourtia sepiaria*	99	11
Capparidaceæ	*Capparis grandis*	1	0
,,	*Capparis sepiaria*	8	3
Combretaceæ	*Anogeissus latifolia*	8	0
Convolvulaceæ	*Argyriea cuneata*	108	0
Diosoreaceæ	*Dioscorea oppositifolia* ..	15	0
,,	*Dioscorea bulbifera*	16	2
Ebenaceæ	*Diospyros melanoxylon* ..	8	1
,,	*Diospyros montana*	18	2
Euphorbiaceæ	*Breynia rhamnoides*	24	0
,,	*Flueggia leucopyros*	29	0
,,	*Phyllanthus polyphyllus* ..	29	3
Leguminoceæ	*Acacia leucophlœa*	2	0
,,	*Acacia sundra*	7	2
,,	*Acacia pennata*	40	10
,,	*Albizzia amara*	3	0
,,	*Albizzia oderatissima*	5	0
,,	*Atylosia albicans*	14	2
,,	*Pterolobium indicum*	18	3
Liliaceæ	*Asparagus racemosus* ..	30	2
,,	*Gloriosa superba*	28	0
,,	*Erythroxylon monogynum* ..	34	5
Lythraceæ	*Lagerstrœmia Thomsonii* ..	6	0
Melastomaceæ	*Memicylon edule*	108	15
Meliaceæ	*Chloroxylon swietenia* ..	9	0
Moraceæ	*Cudrania javanensis* ..	11	2
Oleaceæ	*Jasminium rigidum*	809	111
Rhamnaceæ	*Scutia indica*	65	21
,,	*Sageretia parviflora*	16	0
,,	*Zyzyphus œnoplia* .. .	59	9
Rubeaceæ	*Canthium didymum*	28	14
,,	*Ixora parviflora*	23	2
,,	*Canthium parviflorum* ..	5	1
,,	*Webra corymbosa*	81	6
,,	*Randia dumetorum*	2	0
Rutaceæ	*Clausena wildenovi*	51	2
,,	*Toddalia aculeata*	89	0
,,	*Atalantia monophylla* ..	8	1
,,	*Limonia acidissima*	14	0
Sapindaceæ	*Dodonea viscosa*	26	0
	Carried over ..	2,029	232

TABLE II—(*Contd.*)

		Lantana-free	Lantana-infested
	Brought forward ..	2,029	232
Tiliaceæ	*Crewia orientalis*	12	0
,,	*Crewia hirsuta*	15	0
Verbenaceæ	*Premna tomentosa*	9	1
,,	Lantana	0	2303
,,	*Vitex pubescens*	5	0
	TOTAL ..	2,070	2,536

It will be seen that out of 57 species of plants occurring in the lantana-free area 21 are exclusive to the plot and are totally absent from the lantana-infested one; with regard to the other species occurring in both plots, they decidedly preponderate in lantana-free area, where one cannot fail to notice that the plot has been well stocked not only with sandal but also host trees. This is a striking instance where, through human effort, a restoration of the original type has been effected, and the practical bearing of this fact on the control of spike-disease is quite obvious.

Other observations.—(1) It was believed that the earliest age at which sandal gets spiked under natural conditions is 4½ years after flowering. It is now found that a sandal plant two years old in the six-acre regeneration area has been attacked with the disease. (2) A number of weeds growing in the regeneration area were found to suffer from a mosaic disease and aphids were found associated with them. Among the plants which are subject to disease may be mentioned *Gysekia pharmaceoides*, *Laucas asper*, *Malvastrum coromandalianum*, *Rynochosia rufescens* and *Aegeratum conozoides*. This disease has been taken up for further systematic study. (3) Incidence among various girth classes in the Manchi reserve is tabulated below. The results show a greater incidence among higher girth classes.

TABLE III.

Girth class, inches	Number infected	Girth class, inches	Number infected
0– 3	0	21–24	5
3– 6	0	24–27	9
6– 9	4	27–30	3
9–12	6	30–33	2
12–15	5	33–36	0
15–18	10	36–39	3
18–21	7	39–42	4

S. RANGASWAMI.

M. SREENIVASAYA.

Coorg Experiments.

Spread of spike in sandal—South Coorg.—Two cases of spike were found in the Bambookadu 1918 Sandal Plantation (Tithimatti Range) on 18–10–1931. The attacked trees were 1′–3″ and 10″ in girth respectively, measured at the collar, and the host species in their immediate vicinity were, Sadle (*Zizyphus œnoplia*), bamboo (*Dendrocalamus strictus*), *Phyllanthus emblica*, *Randia dumetorum*, lantana, *Eugenia jambolana*, *Grewia tiliæfolia*.

2. It is interesting to note that in the year or two preceding the date of formation of the above plantation, *i.e.*, 1918, spike was prevalent, in what appears to be a very virulent form, both to the North and South of Bambookadu. In the latter case the disease was confined within a radius of two miles to natural sandal, growing in Paisari, the infected area being about 9 miles from Bambookadu. In the former case, the infection occurred in a 1880–1883 Sandal Plantation (Balumony) which is within a mile of Bambookadu. The infection was not transmitted until 15 years later.

3. In the case of the natural sandal, the trees were scattered and removed without difficulty sometime ago, but in the case of the 1880–1883 plantation, aggregating 18.38 acres, spiked trees were removed annually, as the disease spread, until in 1930–31 the whole plantation was over-run. The removals have just been completed.

4. The date on which the disease was first observed is significant and seems to indicate that the infection was transmitted at a time when the prevailing wind was blowing from the infected area to the uninfected. In this connection the Tithimatti Range Officer reports that his observations tend to show that infection appears to occur generally before the South-West Monsoon, the intervening period of rainfall thereby not appearing favourable for the spread of the disease.

A. R. BRAND.

Experiments conducted by the Indian Institute of Science—I.

Ecological aspects of the problem of spike-disease.—Details of the primary sites of attack, with respect to Nellivasal, Sigur and Kollegal spike areas are now available through the kind courtesy of the Forest Officers. These observations further substantiate the theory that agricultural operations are closely associated with the primary sites of infection. Agricultural invasion of a forest brings about a visible change in the floristic aspect of the adjacent area mainly due to the interference caused by man and his domestic animals. He introduces

new crops, new weeds and in consequence, new insect fauna associated with them. A change in floristic composition gives rise to a change in the abundance and variety of insect fauna, a study of which is a matter of considerable practical importance to the problem of spike-disease.

Preliminary surveys of a few of the primary sites of spiking have been completed and more of them will be examined during the next quarter. The new invaders of the denuded area have been closely investigated and many of them are found to be affected by either a mosaic or a leaf curl, significantly absent from healthy areas. Several of them were found associated with aphids and green Jassids reputed to be vectors of virus diseases. The importance of a study of these diseases is realized, if attention is called to the fact that many of these affected shrubs make excellent hosts for the parasitic sandal. Experiments on the mechanical transfer of these mosaics to sandal have already been initiated and the problem of specific vector transmission and haustorial transfer of these diseases is being taken up. The foregoing discussion shows that there are three aspects to the study of the primary sites of attack, the ecological change leading to (1) predisposition of sandal plants to disease, (2) introduction of the causal entity borne by new invaders, and (3) change in faunistic composition resulting in the establishment of disease vectors. We suggest that a prevention of the above change, which is largely brought about by human interference, is the best means of protecting our healthy sandal areas, while in the case of predisposed sites, where the change has already been initiated or completed, a reversal of the conditions to the original state constitutes the most rational means of checking the incidence and spread of spike. The problem of disease-control is therefore largely one of judicious sylviculture and intelligent plant sanitation, details of which will be drawn up in the light of the recent researches on the physiology of sandal.

Transmission in relation to host plants.—Transmission studies have revealed that comparative immunity is acquired by sandal plants parasitizing *Ruta graveolens*, while those with Divi-Divi are rendered particularly susceptible to artificial grafts.

M. SREENIVASAYA.

Y. V. SREENIVASA RAO.

Experiments conducted by the Indian Institute of Science—II.

Field experiments.—Reconnoitring survey of the Sanamavu Reserve Area which has so far remained healthy was carried out. A stream runs through the area. The stock of sandal is good and, particularly alongside the stream, very high. The hosts largely abounding are *Pongamia glabra*, *Rhus mysorensis* and *Eugenia jambolana*. The following species were also met with:—*Carissa conandus*, *Dichrostacys cinerea*, *D. viscosa*, *A. pennata*, *Breynia rhamnoides*, *Scutia indica*, *Caparis sepiaria*, *Cassia montana*, *C. anniculata*, Lantana, *Z. jujuba*, *Z. œnoplia* (healthy and spiked), *Vitex* sp., *Randia duematorum*, *Canthium didymum* and *Flueggia leucopyrus*. Sandal was healthy and bore flowers and fruits.

Treatment of spiked sandal with chemical reagents.—Some preliminary experiments were carried out to determine the best method of checking the spread of spike in an infected area. This could be achieved only when the diseased plant is killed quickly by the application of deadly chemical agents. Various substances such as compounds of arsenic, mercury and copper are known to be poisonous to plants. Among the organic chemicals ethylene oxide has been found to be very useful in eradicating a variety of noxious weeds. In the case of big plants like sandal, the concentration of the poison and its penetrability are important factors determining its efficiency. Most of the chemicals will be mostly precipitated in the soil; so, their application through that medium was not considered suitable. Spraying of the chemicals on the trees was also considered to be unsatisfactory.

The method that was tried consisted in exposing the soft wood after the removal of bark and treating the same with the various solutions mentioned below. Injection was also tried in a few cases. The following solutions were tried:—'Atlas' Tree Killer, Ferrous sulphate (conc.) and Copper sulphate (conc.). The treatment was carried out in two ways:—(1) by girdling the tree near the base, removing the bark completely and smearing known quantities of solutions till they were absorbed, (2) by removing the bark upto the corky layer and then applying the solution. Six plants were treated in each case. The experiment was carried out in a spiked area with diseased trees. The effect of the same solutions on healthy plants will be studied at a later stage.

'Atlas' solution used by some of the earlier workers would appear to have been of variable composition. This would partly account for the divergent nature of the results obtained at different periods. The solution used in this investigation was alkaline and gave a precipitate on addition of hydrochloric and sulphuric acids. The solid content was 43.25% on the weight of the solution, of which nearly 80% could be accounted for as aresenious oxide, thereby indicating that arsenic is the active ingredient of the solution. The

solution also contains caustic soda which would appear to have been used to dissolve the arsenic.

Results.—*I. One month after treatment.*—1. (*a*) *Tree treated with $FeSO_4$ solution after full girdling.*—Foliage partly shed. 50 per cent. of leaves still living. The disease in partly affected ones has advanced. (*b*) *Trees treated after light girdling.*—Not affected at all. The disease has progressed. 2. *Trees treated with $CuSO_4$ solution after full and partial girdling.*—50 per cent. of foliage still alive but the disease has not progressed. 3. (*a*) *Trees treated with 'Atlas' Normal Solution after full girdling.*—All are dead. In a few of these a tendency of the leaves to wither in general was noticed even after 4 days after treatment in spite of the rain that set in sometime after treatment. (*b*) *Trees treated with 'Atlas' Normal Solution after partial girdling.*—Not yet dead. Leaves mostly withered. The trees on which injection was tried are also not affected.

II. Two months after treatment—1. *$FeSO_4$ treatment.*—Leaf fall general but varies from 40% to 75% of the crown. The disease in partially affected ones has advanced and no further effect has been noticed on the fully affected plants. This is true in the case of full girdling, and slight girdling although in the latter case, the disease has not progressed in two cases. Plenty of new flush has come up. No withering characteristic of death of the leaves has been noticed.

In the case of plants injected with the solution, fresh spiked flush has come up. In the control plants, light shedding of foliage has been noticed. The disease has progressed. 2. *$CuSO_4$ treatment.*—Very moderate shedding was noticed. The disease has advanced in this case as well. In the case of light-girdled plants, the effect of the treatment is not encouraging. The disease has advanced in spite of the treatment. In the controls half the number of plants have been further affected. In the injected plants, further progress of the disease has been registered. 3. *'Atlas' solution treatment.*—All the trees are dead, which were treated with the solution after full girdling. In the light-girdled ones 50% are dead and the rest have put on new flush. The controls show a further but slow progress of the disease.

Further experiments with other chemical agents and substitutes are in progress.

Laboratory.—The lines of work indicated in the previous report have been continued.

A. V. VARADARAJA IYENGAR.
S. RANGASWAMI.

Entomological Investigations by the Forest Research Institute—I.

Bangalore insectary.—The new insectary so kindly provided by the Indian Institute of Science includes one big wire-gauze cage measuring $40' \times 20'$, eight small cages, each measuring $5' \times 3'$, and a building providing 40 ft. of North-facing working bench together with rooms for stores and office work.

The transmission experiments which were commenced in thatched sheds in April 1931 at Denkanikota have now been resumed at Bangalore. The new insectary has become a great asset to the entomologist and all works in progress, including some 200 experimental plants, have already been transferred from Denkanikota to the Bangalore insectary.

Transmission experiments.—One hundred and twenty sandal plants in pots experimented with *Moonia variabilis*, *Petalocephala uniformis* (*Jassidæ*), *Sarima* sp. (*Fulgoridæ*), *Sympiezomias cretaceus*, *Derodes sparsus* and *Myllocerus* sp., and (*curculionidæ*), under controlled condition are under observation at the Bangalore insectary. The sandal plants are all of the same age, with the same host plants and are covered over by specially designed and treated muslin-cellophane cages. *Results.*—The leaf-desease (*Chlorosis*) caused by *S. cretaceus* beetles reported at the last Spike Conference has been reproduced. It is now definitely proved that not only *S. cretaceus*, but also *D. sparsus* and *Myllocerus* sp. can produce the symptoms of this leaf disease and feeding even for 2½ days by spike-fed individuals on healthy sandal plants is enough to impart the disease. Experiments with *M. variabilis*, *P. uniformis* and *Sarima* sp., have so far yielded negative results. Experiments with *Tambinia verticalis* (*Fulgoridæ*) could not be taken up because it has not been possible to rear this species on sandal successfully. In pot E 37 at Denkanikota, I was able to raise this species upto the third nymphal stage in April last but they died all of a sudden. From May till December attempts to rear this species, both under field and laboratory conditions, have been made with about 300 individuals, but so far no success has been achieved. Field studies with insects of sandal and associates lead me to conclude that *T. verticalis* (1) breeds on *Canthium didymum*, (2) it occurs in large numbers in areas where *C. didymum* abounds, and (3) it does not normally breed in sandal. This species is very often found on sandal but its occurrence on sandal should be regarded as that of a migrant.

Indicator plots and quantitative collections.—The one-year quantitative collections from the indicator plots Nos. 1 to 21 situated at Fraserpet, Jawalgiri and Aiyur stations in North Coorg and North Salem districts were completed on the 30th September 1931 and those from Nos. 22 to 28, in Kottur (Vellore district) by the 15th December 1931 according to the sanctioned plan of operations.

The above-mentioned sample plots represent typical forest growth in each working station, and are distributed in both healthy and spiked areas. They were therefore considered to be ideal for both quantitative survey and ecological studies. The following are the dominant species associated with sandal on the different plots:—

Plot No.	Associates of sandal	Condition of sandal	Locality
28	*Dendrocalamus* ..	Healthy	Kottur
3	*Dendrocalamus*, *Anogeisus* ..	Spiked	Fraserpet
7	*Dendrocalamus*, *Anogeisus*, *Zizyphus* ..	Healthy	Fraserpet
21	*Dendrocalamus*, *Anogeisus*, *Canthium* ..	Healthy	Aiyur
23	*Anogeisus*, *Murraya* ..	Healthy	Kottur
25	*Zizyphus*, *Breynia* ..	Healthy	Kottur
4	*Zizyphus*, *Pterocarpus* ..	Spiked	Fraserpet
2	*Zizyphus*, *Flemingia* ..	Spiked	Fraserpet
20	*Zizyphus*, *Pittosporum* ..	Spiked	Aiyur
10	*Zizyphus*, lantana, *Dodonæa* ..	Spiked	Jawalgiri
11	Lantana, ..	Spiked	Jawalgiri
6	*Jatropha*, lantana ..	Healthy	Fraserpet
5	*Albizzia*, lantana ..	Spiked	Fraserpet
15	*Acacia*, lantana ..	Healthy	Aiyur
9	*Acacia*, lantana ..	Spiked	Jawalgiri
19	*Acacia*, lantana ..	Spiked	Aiyur
16	*Canthium*, *Acacia*, lantana ..	Healthy	Aiyur
14	*Acacia*, lantana ..	Spiked	Jawalgiri
27	*Canthium*, lantana ..	Healthy	Kottur
26	*Canthium*, *Acacia* ..	Spiked	Kottur
8	*Dodonæa*, lantana, *Jasminum* ..	Spiked	Jawalgiri
13	*Canthium*, *Dodonæa*, lantana, *Jasminum* ..	Spiked	Jawalgiri
12	*Shorea*, *Memecylon*, *Dodonæa*, *Jasminum* ..	Spiked	Jawalgiri
18	*Memecylon*, *Dodonæa*, *Scutia*	Healthy	Aiyur
17	*Strobilanthus*, *Memecylon*, *Scutia*, lantana ..	Healthy	Aiyur
22	*Tectona*, *Cipadessa*, *Zizyphus* ..	Healthy	Kottur
1	*Tectona*, *Grevillia*, *Flacourtia* ..	Spiked	Fraserpet
24	*Tectona*, *Ficus*, *Zizyphus*, *Dendrocalamus*, *Breynia* ..	Healthy	Kottur

Grass was present on all the plots.

The criterion used in fixing the limits of the indicator plots has been the estimation of an approximately equal volume of foliage which certainly

depended on the number and size of the sandal trees growing in the plot. This procedure was necessary since sandal trees of the same age, height or girth classes each having an equal amount of foliage could not be found under field conditions. Thus each sample plot has approximately the same amount of foliage and the actual time spent daily in collecting insects from sandal by both beating and sweeping methods, in each plot, by each field assistant was 4 hours excluding the time taken by him to go from one tree to another. Each sample plot contains 75 to 130 sandal trees and collections have been made from 7 A.M. to 1 P.M. daily on the foliage and growing shoots of sandal trees alone, throughout one complete year.

The finer methods employed in the study of insect ecology in forests of America and elsewhere cannot be applicable to forest conditions prevalent in India, more particularly in sandal forests. For example, our ideal sample plot should be such that if it is to represent, for example, *Dodonæa*-sandal association, it must be immediately surrounded by a large vegetation in which *Dodonæa* and sandal are the only dominant species and not by vegetation in which lantana-sandal or *Zizyphus*-sandal are the dominants. The underlying idea being that when the insect fauna, during collections in the *Dodonæa*-sandal plot are disturbed, they would fly and settle on the same dominants outside the plot and when the normal conditions are restored, the same fauna will be found on the trees in the plot. Thus comparisons of the insect fauna between the different associates are made easy. Such ideal plots in practice cannot be found in sandal jungles, and as such we have to devise our own methods according to conditions present in each station for ecological studies.

The object in making quantitative collections in the different indicator plots was to see if the components of the insect fauna, in the several plots with different host associations, located both in healthy and spiked areas, would, by statistical methods, give a clue to the determination of insect or insects responsible for the spread of the spike-disease of sandal.

The quantitative collections can be looked upon from two points of view:—(*a*) if the host plants have an influence on the insect fauna of sandal, and (*b*) if the host plants do not have any influence on the insect fauna of sandal. If the former hypothesis is true, then according to our present conception the preference of a particular insect or insects to particular plants is regarded as guided directly by the specific chemical gustatory or olfactory properties of the plants themselves. Taking into consideration the unique parasitic nature of the sandal plant, which depends mostly on the associated plants for its food supply, each of the indicator plot has a certain potential value and the sandal tree growing in the plot can be taken to represent the index of the physiological conditions. If the food supply of sandal insects determined by volume of foliage is the same or constant and the actual collection is done by a fixed time standard, *i.e.*, 4 hours daily, then the factor

of associated host plants or, in other words, the effect of food combinations on sandal in different indicator plots can be measured and is comparable interse. The collections of insects made on sandal in different plots should therefore be comparable both quantitatively and qualitatively though it must be admitted that insects, on account of their mobile nature, are in themselves a very variable quantity.

If the second hypothesis is true, then the selection of indicator plots, making quantitative collections in them and many other items of work in this investigation, should have no bearing on the problem, in which case we must look to some other source for a clue to the solution of the problem.

Quantitative collections to the extent of about 600,000 insects have been despatched from the field to Dehra Dun, where they have been analysed statistically by Mr. Dover.

Enemies of sandal.—In studying the malady of a plant it is essential to know what are its natural enemies. A few that have come to my notice during the course of my field work are here mentioned. One species of *Microlepidoptera* has been seen to feed on sandal flowers. Five species of *Lymantridæ*, five species of *Geometridæ*, two species of *Lasiocampidæ*, two species of *Cochlididæ*, four species of *Psychidæ*, two species of *Noctuidæ*, one species each of *Pyralidæ* and *Syntomidæ*, three species of *Curculionidæ* and one species of *Locustidæ* have been found to feed on leaves of sandal. One species of *Microlepidoptera* has been seen to mine the leaves of sandal. One species each of *Pyrilidæ* and *Curculionidæ* bore in twigs of sandal while one species each of *Lamiidæ*, *Zeuzeridæ* and *Hepialidæ* bore in sandal shoots and saplings. One species of *Cerambycidæ* is known to girdle sandal shoots, while one species of *Buprestidæ* is known to bore in sandal roots. In addition to the above, dead twigs of sandal have been found to be infested with *Scolytid* beetles and the wood of dead saplings is attacked by various species of *Bostrichidæ*, *Buprestidæ* and *Longicorans*. The names of the sap-sucking insect enemies are given in my first Quarterly Report.

Enumeration of 838 sandal trees made at Hanumanthrayangudi at Aiyur showed that apart from the deteriorating effect which might be produced on the parasitic sandal as a consequence of unhealthiness of the associated host plants, sandal was subjected to injuries made by its insect enemies mentioned above as also to those caused by browsing and trampling by deer and cattle, strangling by creepers, other maltreatment by man and animal and lastly by fires. A general or specific condition of unhealthiness was always found to be present in almost all the trees enumerated. Some of the species responsible for causing the general stag-headedness of sandal are mentioned in the first Quarterly Report. The above would give an idea of the various factors responsible for reducing the vitality of the sandal plant and to make it more susceptible to the spike-disease.

Observations on Coccidae.—Jawalgiri is a heavily spiked area, but the general incidence of coccids on sandal in this area is far less than that observed in Aiyur forests which is a healthier area. At Fraserpet, Aiyur and Jawalgiri, individual sandal trees with a heavy infestation of the black-scale, *Lecanium nigrum*, N. have been met with. Such trees were always found to be healthy. On analysing the records of enumeration made at Aiyur, it was found that 15 per cent. of the sandal trees harboured coccids: of the former 1 per cent. was spiked but the remaining 14 per cent. were perfectly healthy. All the spiked sandal trees and also trees with coccids were completely removed from the area and 459 sandal trees, were examined every month for one complete year, for appearance of coccids and the onset of spike disease. The results indicate that sandal trees on which coccids appeared remained healthy throughout the period under observation, and that coccids began to appear on trees that had already got spiked from the month of August onwards. In not a single instance did a "coccid-present not spiked tree" become "coccid-present spiked tree". In all, twelve species of coccids are known to feed on sandal and a short note on coccids has been prepared.

Observations on Cicadidae.—Between October and March, before the emergence of adult cicadids, the earth along the roots of twelve sandal trees was dug up to a depth of 24″ at Jawalgiri and Aiyur and the earth sieved with a 24 mesh sieve. The young cicadids are known to lead a subterranean life, sucking the juice from finer roots of trees. In these operations, not a single cicadid nymph was met with, so it is concluded that the young cicadidæ have nothing to do with the transmission of the disease.

During 1930 adult cicadids appeared by end of March (29th) in N. Salem and N. Coorg. They were found in large numbers from about the 12th April to end of May and stragglers were caught uptil the 12th June. During 1931 cicadids appeared rather late. They were first seen on the 17th April in N. Salem, on the 2nd April in N. Coorg and on the 13th April at Kottur. They were seen in hundreds during the latter part of April and throughout May. Stragglers were caught on the 19th June at Aiyur and as late as 4th August at Kottur and at end of August in N. Coorg. Seven species of cicadids have so far been collected from N. Salem, N. Coorg and Vellore localities. The cicadids during the process of feeding remain stationary some time to the extent of 2 hours, and eject their fluid excreta in the form of fine spray. This fluid excreta from *Platypleura hampsoni*, *P. octoguttata* and *Limuriana apicalis*, while feeding on spiked plants, has been collected and introduced in seven sandal plants at Aiyur, and the trees kept under observation.

Bionomic studies.—Field notes on the bionomics of over 80 insect species, intimately associated with sandal, have been made and some of the important observations are here mentioned. *P. uniformis* and *Ledra mutica* (*Jassidæ*) oviposit in fine slits made by the ovipositor inside succulent sandal shoots as

also in shoots, a little over the thickness of a pencil. In the case of succulent shoots, the slit heals up and a fine scar $\frac{1}{2}''$—$\frac{3}{4}''$ is left, while in the case of thicker shoots, the bark cracks and a bigger scar sometimes exposing the wood is left. The slit made by *L. mutica* is similar but smaller in size. *Acropona prasina* (*Jassidæ*) oviposits inside the tissues at the axil of leaf and shoot. *M. variabilis* (*Jassidæ*) oviposits inside the tissues, (*a*) at the axil of leaf and shoot, (*b*) at the base of axilliary shoot, and (*c*) inside green succulent shoots. *Phyllyphanta* sp. and *Melicharia lutescens* (*Fulgoridæ*) oviposit inside the bark of shoots and the eggs are not laid deep. The place where the eggs are laid is slightly raised and swollen. When the eggs are laid close together a fine slit and a scar is formed. *T. verticalis* (*Fulgoridæ*) oviposits, (*a*) in the bark of shoots, (*b*) inside the tissues of succulent shoots, (*c*) inside the petiole of a leaf, and (*d*) in the mid-rib of a leaf. *Sarima* sp. (*Fulgoridæ*) oviposits on the surface of buds, new flush, leaves and shoots. *Eurybrachys tomentosa* (*Fulgoridæ*) oviposits in clusters on shoots, stems and leaves. Eggs have been found to be laid between the upper and lower surface of leaves at the margin and also on sandal leaves transversely in two rows, but the identity of these is not yet known. The female of the locustid *Phaneroptera* sp., in her attempts to oviposit lacerates the bark of sandal shoots indiscriminately with her curved, strongly chitinised, saw-like ovipositor with the result that when the bark contracts and dries up, a big scar $\frac{3}{4}''$—$2''$ long is left. The shoot with the teased bark looks as if it has been crushed with a stone. *Phaneroptera* sp. oviposits inside sandal shoots.

P. hampsoni, *P. octoguttata*, *Cryptotympana intermedia* and *L. apicalis* (*cicadidæ*) suck sap from shoots and stems of both healthy and spiked sandal trees in the adult stage. *P. uniformis* throughout the nymphal stages, feed on sap from leaves and in the adult stage on shoots. *A. prasina* in the first and second nymphal stages feed on leaves and in the third, fourth and adult stages on shoots. *M. variabilis* and *L. mutica* during both the nymphal and adult stages feed on petiole of leaf and shoot. *Phyllyphanta* sp. and *M. lutescens* in all nymphal stages feed on leaf. The leaf pales and drops off after a time. In the adult stages they suck sap from the shoots. *Sarima* sp. and *Tatva bufo* feed on sap from leaves in the first two stages: during the third, fourth, fifth and adult stages they feed on shoot and petiole of leaf. *E. tomentosa* feeds on the new flush and tender shoots during the earlier stages and on the shoots during the later nymphal and adult stages. Due to effect of mass feeding of 24 individuals of *P. uniformis* or *Sarima* sp., a sandal shoot or young seedling has been found to shed its leaves completely and to die back within 2 months. The progeny from two *L. nigrum* (*Ciccidæ*) females caused the dying back of sandal shoots within 5 months.

The mouth parts of many of the sap-sucking insects of sandal have been studied. They show no peculiarities and are of the usual suctorial

type. A study has been made of the ovipositors of the commoner Jassids and Fulgorids and also of the *Locustid phaneroptera* sp. The ovipositors in some are remarkable in the fact that they are valvular, strongly chitinised and cernate, serrate, strongly serrate and so forth. The gonapophyses bear very fine teeth or cutting edges, are raspate like a file, and are specially adapted for lacerating plant tissues during the process of oviposition.

Life-history studies.—Twenty-six life-history cages are under observation at the insectary. A few minor details with regard to the life-history studies of *P. uniformis*, *Sarima* sp. and *M. variabilis* have been completed and the life-history studies of *A. prasina*, *L. mutica* and *E. tomentosa* are very near completion. All the species mentioned above pass through three generations in a year and the generations overlap. Except *E. tomentosa*, all the species have an adult life of three or more months. Life-history work with other species is also in progress.

The life-history of several defoliators of sandal have been worked out and a note on them prepared. One species each of a *Lamiid* (shoot-borer) and a *Lepturinæ* (dry bark feeder) have also been reared. Rearing work in the insectary has shown that *Moonia diversa* is the female and *Moonia variabilis* is the male of one and the same species. The species identified as *Petalocephala nigrilinia* is not *P. nigrilinia* and whatever may be its later name, it is the male of *P. uniformis*.

My thanks are due to Drs. M. O. Forster and V. Subrahmanyan for their interest in the work and kind efforts towards the construction of the insectary in the premises of the Institute, and to Messrs. J. E. M. Mitchell and S. Rangaswami for all assistance in connection with the experimental work at Denkanikota. Lastly, I wish to record my appreciation of the work done by the field staff, particularly of Mr. Appanna, Insectary Assistant, during my absence.

N. C. CHATTERJEE.

Entomological Investigations by the Forest Research Institute—II: Work done at Dehra Dun.

Systematic work has been continued in the quarter under review, and the sending of North Salem and Coorg material to specialists has been completed. Sir Guy Marshall has arranged for the determination of several families of *Rhynchota*, parasitic *Hymenoptera* and *Coleoptera*, and extensive batches of beetles were sent to Mr. K. G. Blair in addition to those despatched during the previous quarter. Anthribid beetles were sent to Dr. K. Jordan (Tring) and longicorns to Mr. J. C. M. Gardner (on leave in

London). The moths have been sent to Mr. T. Bainbridge Fletcher, Imperial Entomologist, Pusa.

Reports on various groups have already been received from Dr. R. Kleine (*Lycidæ* and *Brenthidæ*), Dr. W. Horn (*Cicindelidæ*), Dr. C. F. C. Beeson (*Platypodidæ*, *Scolytidæ* and *Bostrychidæ*), Mons. E. Fleutiaux (*Elateridæ* and *Melasidæ*) and Dr. K. Jordan (*Anthribidæ*). It is expected that many more reports will be received during the forthcoming quarter and that prompt publication will be possible. Several batches of identified insects, including an extensive selection of weevils, have been received from Sir Guy Marshall. A considerable amount of editorial, analytical and routine work has been done in connection with the above.

The survey of the sample plots at Kottur Yellagiri has been completed and will be generally discussed in the next report.

Relations with specialists on virus diseases have been continued, and much useful literature and information has been accumulated in this way. Dr. Kenneth M. Smith thinks that our selection of species for experimental work is justifiable, and has also made some valuable suggestions which have been passed on to Mr. N. C. Chatterjee.

An elaborate insect trap for studying the effects of wind directions on the dispersal of insects in sandal areas was prepared under the supervision of Mr. R. N. Mathur, Officer-in-charge of the Forest Entomologist's Insectary. This trap has now been despatched to South India, and should provide interesting results.

C. DOVER.

378-32 Printed at the Bangalore Press, "Lake View," Mysore Road, Bangalore City.

Experiments conducted by the Madras Forest Department in collaboration with the Indian Institute of Science—I.

Primary attacks of Spike-Disease.—A case of primary attack was reported in Galigattam R. F. of the Dharmapuri Range. On inspection it was found that the area was situated at a distance of two miles S.-S.-W. of the Marandahalli area which is spiked since 1919. The area lies 1½ miles south of Sithapuram unreserve where a recrudescence of disease was noticed in 1931 and 6 miles S.-E. of Theluwabetta area spiked since 1915.

Nearly 200 acres of the reserve has been affected; the forest is of the open scrub type interspersed with patches of semi-evergreen shola. The average elevation of the reserve is about 3,500 ft. above sea-level. The stocking of sandal in the area is very thick and the infection has started in a spot where the sandal stock is thickest. The area has been subject to exploitation of bamboo and sandal. Thick patches of lantana point to the past occurrence of denuding agencies including fires.

Cultivation is only six furlongs from the affected area and the agricultural crops raised therein suffer from various diseases including the spiking of the common mustard. Weeds associated with agricultural operations, like *Leucas asper*, *Aegeratum conozoides*, *Malvastrum coronandaliunum*, had invaded the affected area and were suffering from mosaic characteristic of other spike areas.

257 sandal plants of various girth classes were found spiked in the area; none were dead of the disease. Considering the nature of the forest growth and the stage of disease, the first attack should have occurred in May 1930. We have no data, however, by which we can determine the period at which the actual infection has occurred in the area.

Spike, mosaics and leaf-curls on Manchi unreserve.—An epidemic spread of spike was observed in the Manchi unreserve, 352 trees having succumbed to the disease during the quarter under review as against 182 for the previous 12 months. The mosaics and the leaf-curls had affected the shrubs and herbs in the area with greater virulence. In fact the disease was noticeable on every plant of *Aegeratum conozoides*, *Leucas asper*, *Gisekia pharmaceoides*, *Centratherum anthelmaticum*, *Cipadessa fruiticosa* and *Vicoa indica*. The parallel spread of these diseases among the associated shrubs and herbs in an epidemic form is very significant.

Masking of disease and pollarding of sandal plants.—In 1929, in the course of transmission studies one of us (M.S.) found that a few sandal plants grafted upon with infective tissue did not manifest the disease symptoms in spite of the

2 F

success of the graft. They were believed to represent the disease-resistant varieties and all of them put on normal growth, both in girth and height. After about a year and a half a few of them were lightly pruned and a fortnight after the disease appeared on most of them in a virulent form with the bursting of dormant buds. This practice of pruning has since been found extremely useful in forcing out disease symptoms and also in establishing if an apparently healthy tree is free from infection or not.

The sandal plants which thus mask the symptoms constitute treacherous sources of infection, since it has been shown by experiment that disease can be transmitted to other healthy sandal plants by grafting some of the tissues derived from them. Eradication of spike in affected areas would not, therefore, be complete unless those sandal plants masking the disease are also eliminated. Non-removal of such apparently healthy plants has been partly responsible for the successive recrudescences of disease, often in epidemic proportions. In any scheme of eradication of spike disease, therefore, it is essential that pollarding should be adopted for forcing out the masked symptoms from apparently healthy trees.

(*a*) In dealing with Manchi and Galigattam areas this method has been adopted. In Manchi 52 trees were pollarded and 11 of them have manifested disease symptoms while rest continued healthy. If the area under experiment is representative of the entire affected area, it would mean that about 21 per cent. of the trees have masked the symptoms, which should immediately be eliminated. With this end in view, 3,000 trees and 1,000 saplings in the area have been pollarded.

(*b*) In the six-acre regeneration plot at Jawalgiri 75 plants were pruned on 3-2-1932. Two of these plants have succumbed to the disease, showing that about 2.6 per cent. of the plants stocked in the area harbour the infection. It is significant that these spiked plants are associated with cajanus and pongamia—host plants which have been found by experiment to render sandal particularly susceptible to disease.

Grafting and Disease Resistance.—Resistance to graft infection exhibited by some of the sandal plants has been the most hopeful feature of the investigation. Transmission experiments at the Institute have established that this property is mainly controlled by the associated host plant, although autogenic factors of disease resistance appear to exist in sandal. Sandal plants growing under certain environmental conditions rapidly succumb to the artificial infections while there exist other sylvicultural conditions which render the sandal plants stocked in the area resistant to disease. Mahadeswarangudi area is a remarkable instance in point. It represents an environment where artificial disease transmission has been a complete failure as contrasted with the successful transmissions we have been able to obtain both at Jawalgiri and Chinnanahalli. The explanation is to be found in the strikingly different floristic aspects presented by these areas.

Soil profile studies.—Among the predisposing factors which have been found to render sandal susceptible to disease, depth and extensiveness of the root system of the associated host plant plays an important part. The greater the volume of soil commandeered by the root system, the greater, ultimately, will be the nutrition made available to the parasitic sandal. The depth and intensity of the root system of a particular area will, therefore, give us an idea of the potential resourcefulness of the area to bear sandal. These studies have been extended to (1) spiked areas, (2) healthy areas and (3) non-sandal areas. The results which are very striking are given in the following table:—

	Spiked area	Healthy area	Non-sandal area
Humus layer ..	2″	6″	15″
Lowest depth to which roots had penetrated ..	24″	72″	72″
Number of roots ½″ and above in diameter found in the profile			30

It will be seen from the above table that sandal-bearing areas in general have a small number of big sized roots in a given section of the soil profile while more than four times the quantity of roots are to be found in a non-sandal area under similar circumstances. Spiked area is characterised by a poor root system, both as regards depth and intensity, a factor which favours the incidence of disease. It must be pointed out that the strikingly higher quantity of root system found in the non-sandal area is perfectly natural since the denuding effect of the parasite does not exist in the area. Pot culture experiments have shown the voraciousness of the parasite to the extent of killing its own host. As a result of intensive parasitism, the root system of the host is reduced and its top growth arrested. These laboratory findings have found surprising confirmation in the soil profile studies. The importance of these studies on the sylviculture of sandal will be discussed in the next quarter.

A. M. C. LITTLEWOOD.
S. RANGASWAMI.
M. SREENIVASAYA.

Experiments conducted by the Madras Forest Department in collaboration with the Indian Institute of Science—II.

1. **Field Experiments.**—*Experiments on the Prevention and Cure of Spike.—1. Treatments with plant poisons:*—(*a*) *Iron sulphate.*—Application either after full or partial girdling or through holes bored in the stem, has resulted in only one plant drying in each case, but others continue unaffected. (*b*) *Copper sulphate.*—Treatment after light girdling is ineffective, while the same after full girdling has resulted in one plant being dead, one not affected and the remaining four showing the portion above the treated part dead. The plant injected with copper sulphate is found to be dead. (*c*) *Atlas solution* is very effective where the application has followed full girdling.

2. **New Experiments.**—During February 1932, 275 diseased plants were treated in various ways. In addition to the solutions mentioned above, trials were also carried out with a substitute for Atlas containing Arsenic, Iron sulphate containing sulphuric acid, Phenol, Copper sulphate, mixtures of Phenol and Copper sulphate, Salt, Tar and a few others. In the case of Atlas, plants of various girth classes were experimented upon. The different substances were tried in solution and also, in some cases, as solids bunged into holes bored in the plants.

Atlas solution.—(*a*) *Full girdling and application of solution.*—98 trees ranging between 2 and 24 inches in girth have been treated. 50% of the treated ones show signs of death within short periods. Further experiments on the standardization of dose to ensure the killing of all the treated plants are in progress.

(*b*) *Light girdling and subsequent treatment.*—The treatment has not produced any visible effect so far.

(*c*) *Coppicing and smearing* the exposed parts in a number of instances has led to immediate success.

(*d*) *Treatment with a substitute for Atlas solution.*—The results are not very encouraging. Possibly greater quantities of the solution are to be applied. In the coppiced plants, the treatment has given quite positive results.

(*e*) Applications of dilute solutions of (1 : 1) of the different plant poisons have not led to encouraging results.

(*f*) Boring holes and filling up with known quantities of the poisons has been found to be highly effective.

It would be interesting to know whether root-suckers are also killed when the mother plant is treated. The available evidence is meagre, though in one or two cases, the suckers were also found dead. Experiments to test the above have already been carried out and results are awaited. Another point of interest is

to know whether the portion below the exposed and treated part remain green or die out quickly. In a few cases, epicormic shoots have been noticed. Experiments to verify this are also in progress.

Iron sulphate either in concentrated or diluted condition, has not produced any visible effect in a month's time. *Phenol.*—In two trees, the leaves have withered. *Tar.*—No effect is visible till now. *Copper sulphate.*—No effect. *Phenol and Copper sulphate* (1 : 1).—No effect. *Common salt* was applied as such by filling up holes bored in plants. Eight plants were thus treated, but only three of them have so far shown any leaf-withering, although the salt was found to have been absorbed by the plants.

Field observations.—(1) In Devarabetta, Thalli R.F., there exists a marked difference between the healthy and the spiked localities. In the latter, the vegetation consists almost exclusively of lantana and deciduous plants devoid of leaves : the area is characterized by large numbers of dry and dead stumps of trees. On the other hand, where the disease has not set in, one finds the flora made up of semi-evergreen plants, and, to a large extent, of living trees. (2) Very near Sanamavu R.F. it was found that healthy leaves had silvery patches on the underside. The cause of this is yet unknown. Microscopical examination of these will be made in due course. To prove the communicability of this condition, plants in pots have been grafted in Denkanikota. The results are awaited. (3) Just outside the Mahadeswarangudi observation area, a few twigs on a spiked sandal were observed to have flowers and buds. In the leaf-bearing stalks, the end leaves were big and characteristic of the healthy condition, while the lower ones were distinctly spiked. Such twigs had flowers. Grafts made from this plant have communicated the disease to others. The tree is under observation.

S. RANGASWAMI.
A. V. VARADARAJA IYENGAR.

Experiments conducted by the Indian Institute of Science—Laboratory Experiments—I.

Study of Mosaics and Spikes associated with spike areas.—Experiments on the intercommunicability of mosaics and spikes among associated weeds and their transfer to sandal by mechanical methods have been completed and the results are awaited with interest. The Specific Vector transmission of these to sandal will be taken up in collaboration with Mr. Chatterjee during the next quarter.

Analyses of the healthy and diseased leaves of *Aegeratum* show that the disease is more allied to tobacco mosaic and spinach blight than to sandal spike if the ammoniacal nitrogen figures are taken into consideration. There is a striking increase in the ammoniacal nitrogen to the extent of about 50 per cent. in the diseased leaves of *Aegeratum* while in the case of spike-disease the ammoniacal nitrogen of leaves is not affected. The higher basic nitrogen characterising spiked sandal is absent in this case. The mineral constituents do not show any significant differences.

Sylviculture of Sandal in relation to Disease Control.—(*a*) *Host plants.*—Recent work on the physiology of sandal has shown that sandal is largely influenced by the nature of the associated host plant with respect to its resistance to disease. Leguminous host plants of the acacia family stimulate the sandal plant to a quick and luxuriant growth but render it particularly susceptible to disease. *Cajanus indicus* and *Pongamia glabra* behave in the same manner, and striking confirmation of this fact has been obtained under sylvicultural conditions in the six-acre regeneration plot where a few of the 2-3 year old sandal plants nourished by cajanus and pongamia have already succumbed to the disease. This fact should not, however, discourage the employment of these leguminous plants as host plants since they constitute the best species capable of nourishing sandal in its early stages of growth.

An exclusive feeding of the sandal plant with leguminous hosts of the above type is what should be strictly avoided; other host trees with deep and extensive root systems like *Melia indica*, *Cassia siamia*, Canthium, Ficus, etc., should be provided far in advance, so that, after a year's growth the young sandal will haustorise those species of plants and build up disease resistance. Considerations of soil and climate should regulate the choice of these deep-rooted hosts for the regeneration of sandal and in fact a reconnoitring survey of the surrounding country will suggest the suitable species.

(*b*) *Haustorial formation.*—Haustoria are to sandal what the root hairs are to other plants. Among the conditions for haustorial formation are: (*i*) æration, (*ii*) the character of the root system of the host, (*iii*) species of host plant, and (*iv*) the nature of the sandal seedling itself. Æration helps not only the growth of sandal roots but also stimulates haustorial formation. If the host

plant has a bushy root system with plenty of adventitious roots, the haustorial connections are made with great ease, since the intensity of the root system of the host increases the chances for haustorization. The physical hardness of the host root appears to influence haustorial formation. Sandal has been found to haustorize Ficus roots which are very soft in preference to Casuarina roots. All attempts at inducing haustorization on *Phyllanthus embellica* have failed so far.

Where sandal seedlings are raised in a germinating pot and the root system of the individual seedlings carefully examined, one will be struck with the varied character exhibited by different seedlings. While some seedlings show a remarkable tendency to haustorize anything they come across, others will be found to possess a comparatively poor root system. If a selection on the basis of this haustorizing capacity is made and transplanted with a common host it will be found that those which exhibit a high haustorizing capacity will parasitize the host quickly and later, on grafting, exhibit the property of resisting disease. This is an autogenic property of the individual seed and an attempt is now being made to correlate this property with some morphological character of the seed. It has been found that all seeds from the same parent tree do not possess this remarkable property.

A high capacity to haustorize, irrespective of species of host, is a valuable property which is correlated with disease resistance and the practical value of this discovery in the sylviculture of sandal is quite obvious. The season most favourable for haustorial formation is from October to January as revealed by pot culture studies. It is during this same period that fresh growth of the old haustorial connection also occurs.

(*c*) *Deprival host plants.*—Pot culture experiments have shown that sandal plants, if deprived of their host plants, succumb to the disease quicker. Another interesting fact is that host plants, intensively parasitized by sandal on coppicing, rarely, if ever, putting forth shoots. Further the root system of a parasitized host is stunted and puts on very feeble growth even during the growing season. These observations have a pertinent bearing on the sylviculture of sandal. No exploitation, involving the deprival or weakening of hosts, should be encouraged in sandal bearing areas. The spike areas so far investigated are characterised by heavy exploitation of fuel, timber and bamboo, and this fact should warn us with respect to the management of our present healthy areas.

(*d*) *Denuding effect of sandal.*—The potential regeneration of sandal in a given area is a matter for serious consideration, since the increase in the number of growing and young sandal, year after year, would tax the resources of the environment with respect to its host plants, many of which may gradually be killed or seriously weakened due to overparasitism. In other words, the sandal plant itself has to be recognized as a powerful denuding agent, whose aggressive spread should be kept within optimum limits, which depend upon the availability

of host plants and their size and vigour in the area. This would mean that sandal plants should be thinned down in the case of areas where overparasitism is feared and where introduction of new host plants is not practicable.

(*e*) *Light and Shade.*—Experimental transmissions have shown that a sandal plant kept continuously under shade is more susceptible to disease than a similar one kept exposed to the sun. The plant under shade puts on "soft" growth, has broader and darker green leaves. The "shade" plants take on the grafts with a higher percentage of success and succumb to the disease in larger numbers. This lends experimental support to the observations of Rao Bahadur K. R. Venkataramana Ayyar, who has always held that sandal plants "under suppression" are predisposed plants if not actual infection-bearers, which manifest disease symptoms when they are exposed to the sun. The "shade" plants grafted with diseased tissue behave in essentially the same manner; when brought into the sun they manifest the disease symptoms with the bursting of new buds in response to the stimulus of sunshine. In the sylviculture of sandal "suppression" or heavy "shading" young sandal should, therefore, be strictly avoided.

Season of infection under natural conditions.—With a view to determine the period during which the actual infection occurs under natural conditions, batches of pot cultured sandal plants were sent periodically to a heavily spiked area and kept there for a definite period. The Samayeri grafting plot where scars and disease appear in a very virulent form, was selected for the purpose. Every two months the batch of sandal plants in the area is replaced by a fresh batch, and the old plants supposed to be infected are brought back to the Institute premises. After a month or two the latter are defoliated to force out any symptoms which may be masked. One of the first batch of plants (No. 6), which was kept in the area from 25-4-1931 to 30-6-1931 has got spiked showing that the actual infection has occurred during this period through some agency yet undetermined. The experiment is being continued to see if the infection occurs during other seasons as well.

Reaction of the tissue fluids of healthy and diseased sandal.—The hydrogen ion concentration of the tissue fluids of diseased and healthy sandal have been determined by the colorimetric method.

	Healthy		Diseased	
Leaves	5.7	5.4	5.1	5.0
Stem	5.4	5.2	4.9	4.8
Root	5.6	5.6	5.2	5.2

It will be seen from the above table that the tissue fluids of the diseased sandal, whether it be from leaves, stem or root, has always a greater acidity than

that from the corresponding healthy sandal. Experiments are in progress to find out whether the hydrogen ion concentration is affected appreciably in the cases of sandal kept in sunlight and in shade respectively.

M. SREENIVASAYA.
Y. V. SRINIVASA RAO.

Experiments conducted by the Indian Institute of Science—Laboratory Experiments—II.

1. Physiological factors of disease resistance.—(*a*). *Organic acids.*—Fresh leaf materials from healthy and spiked plants respectively were extracted with water. The extract was concentrated, treated with alcohol and the organic acids precipitated as barium salts. The latter were dissolved in mineral acid and reprecipitated. The free organic acids were finally released by the addition of a slight excess of sulphuric acid and extracted with ether for 320 hrs. The ethereal extract was concentrated, dried and esterified, and the esters, after purification, fractionated. The results from one set of experiments are given below:—

Condition of the plant	Wt. of fresh leaves in gms.	Wt. of esters combined in gms,	Fractions obtained with temperatures
Healthy ..	3,800	5.9	Five { 1. below 100°; 2. 110—130°; 3. 134—137°; 4. 146—149°; 5. above 150°
Spiked ..	1,355	5.6	Two { 1. 105—110°; 2. 140—150°

The identification of esters is in progress. The residual aqueous solution is being analysed for any acid that might not have been taken up by ether. The original material left after water extraction is being studied for acids, chiefly oxalic, which exists as the calcium salt. (*b*) *Tannins.*—Materials derived from Aiyur and other places are being studied for tannins and other phenolic bodies. Tests carried out on extracts of healthy and spiked leaves show some difference between the two types of specimens. (*c*) *Other buffering principles of plant juices.*—Besides organic acids, amino acids and phosphates are important buffers. It has been found that the phosphorus content of the spiked leaf is

higher than that of the healthy one, and titration experiments with leaf saps and phosphate solutions are in progress to determine the extent to which increased titration values in the spiked specimens is due to phosphates.

Analyses.—Specimens of oil derived from heartwood treated with Atlas solution are being subjected to tests for arsenic.

A. V. VARADARAJA IYENGAR.

Entomological Investigations by the Forest Research Institute—I.

Transmission studies.—(*a*) *With leaf-eating insects.*—On the basis of field observations made on *Curculoinidæ* and evidences of leaf disease (chlorosis) obtained from indicator experiments with *S. cretaceus* beetles, three species of Curculoinids, *S. cretaceus*, *Dereodes sparsus* and *Myllocerus* sp. were selected and experiments conducted as follows:—Feed 15 individuals of each on spiked sandal plant for 15 days inside sleeve cages. Transfer the spike-fed individuals separately to healthy plants enclosed in muslin-cellophane cage and allow them to feed on these plants for (1) 2½, 5, 15, 25 days respectively and on the fifth plant, till the death of the insect; (2) 2½, 5, 15, 25 and 35 days after which time, if alive, give a second feed on a spiked plant for 15 days and transfer to the last plant for 35 days, then a third feed and so on till death; (3) 2½, 5, 15, 25 and 35 days after which time, if alive, give a second feed on a spiked plant for 15 days and repeat the experiment on the same series till death. *Control.*—Other details same as above, but feed the beetles on healthy sandal plants.

Experiments under (1) were conducted with *S. cretaceus* beetles only and no controls were kept for this experiment as controls under (2) and (3) were available. These seven sets of experiments were commenced during June and July 1931 at Denkanikota and 65 plants under controlled conditions are still under observation at the Bangalore Insectary. *Results.*—The symptoms of the leaf disease (chlorosis) produced by *S. cretaceus* on sandal are described in the report for the quarter ending 30th June 1931. The leaf disease produced by *D. sparsus* and *Myllocerus* sp. is similar to that produced by *S. cretaceus*. Some of the important facts not mentioned previously are detailed here. The earliest symptoms of the leaf disease (chlorosis) in the form of white blotches, begin to appear on the leaves of experimental plants after 12 weeks from the commencement of the experiment. The blotches become fairly evident by the seventeenth week and become prominent by the twentieth. It was found that the number of leaves with blotches increased with the period of feeding by spike-fed beetles.

At the same time, as the appearance of the white blotches, or a little later, bronze spots appear on the leaf, in clusters, all over or in small isolated groups or continuously in a line forming a sort of border between the white blotch and the green tissue of the leaf. In some leaves the upper surface has white blotches and the lower one bronze spots, while in others the white blotch is very faint, and the bronze coloration prominent, to the extent of sometimes covering the entire leaf. It is not always necessary that the discoloration should first start at the point eaten by the beetles and any leaf or leaves above the bitten leaf may manifest chlorosis. The white blotch or bronze spots, if seen on the upper surface, is not visible on the lower surface of the leaf. The leaf becomes crumpled and begins to curl lengthwise, either over the upper or lower surface sometimes before the blotches appear and at a later stage, even when only the white blotch is present the leaf withers and drops off. A small white blotch may appear at the base near the petiole, or at the apex or at the sides of a leaf, which gradually spreads over the entire leaf giving a glistening, ashy-white appearance.

It was also observed that leaf shedding per week was heavier in the experimental plants than in the case of the control ones. In some of the experimental plants the new flush appearing after complete shedding of leaves, manifest the leaf disease (chlorosis) also. The new flush in the case of one plant (No. 274) is distinctly small. It is also of interest to mention that the average life of beetles, which had fed on spiked leaves, was shorter than that of those fed on the healthy ones. The crumpling and curling of leaves are less marked in plants under (1), but was more marked in the fifth plant under experiment (2) and in plants under experiment (3), where more than one spike feed was given to the beetles. Two plants died during the course of the experiments.

Out of 65 plants under observation, all the 35 experimental plants showed the leaf disease, while none of the 30 control plants showed any.

It may be pointed out that each batch of beetles was given only one feed on spiked leaves initially and the experiments were run for 82½ days, and also, that in experiment (3) total periods of 82½ and 180 days elapsed before the beetles had the second and third feed on spiked leaves. It is, therefore, believed that if quicker feeds on diseased and healthy plants are alternately given to the beetles, different results would be obtained.

From the above, the following conclusions can be drawn:—(1) the beetles *S. cretaceus*, *D. sparsus* and *Myllocerus* sp. can transmit a disease from spiked to healthy sandal, (2) the beetles that had previously fed on spiked leaves carried the infection for at least 82½ days and (3) since this leaf disease has been transmitted by feeding the above-mentioned species on spiked sandal, it is probable that the disease is a part property of sandal spike.

(*b*) *With sap-sucking insects.*—Three species, *Moonia variabilis*, *Petalocephala uniformis* (*Jassidæ*) and *Sarima* sp. (*Fulgoridæ*) were selected on account of their binomics and distribution. The experiments were conducted as

follows:—Fifteen individuals of each species were fed on a spiked plant for 15 days inside sleeve cages. Individuals of each batch were then transferred separately to healthy sandal plants in pots enclosed in muslin-cellophane cages and allowed to feed until they died. The results were noted at fortnightly intervals. In case of breeding the excess population was removed and killed. One set of experiments was conducted each month for one year. *Control.*—Details same as above, but fed the insects on healthy sandal prior to transfer.

The above experiments were started in April 1931 and continued till March 1932. 67 plants, under controlled conditions, are still under observation at the Insectary. In addition to the above, 40 field indicator experiments inside sleeve cages with the above-mentioned species were conducted between November 1930 and October 1931 and have since been under observation.

In our experiments, the suspected vectors, *M. variabilis*, *P. uniformis* and *Sarima* sp. had first fed on diseased source for 15 days and then on the experimental (healthy) plants for at least three months, the duration of their adult life, except in the last two sets of experiments. The experimental plants have been subject to experiment for periods of 1 to 12 months and the indicator experiments for periods of 6 to 18 months. *Results.*—Except for the dying back of shoots of some of the plants due to the action of mass feeding of the insects no disease symptoms of any kind have been produced in them up till now. The upper portion of some of the twigs in plant (Nos. 267, 290, 248 and 366) became dry owing to the mass feeding action of the sap suckers and new flush has come up below the dead twigs. Similar observations have also been made in the case of some of the control plants (Nos. 268 and 142). Distinct shortening of internodes and leaves and also clustering of leaves are visible in plant No. 46 experimented with *P. uniformis*, but none of the control plants show this abnormality so far. Similar records were obtained in case of indicator experiments with plants Nos. E16 and E49 at Aiyur last year and several others in pots at Denkanikota, but all these trees developed healthy flush later. Plant E16 subsequently died back. It has further been observed that the experimental plants Nos. 215, 236, 285, 264 and 298 died during the period of observation. These plants were noted to die back long after the excess population of insects was removed from sandal.

If the suspected vectors, *M. variabilis*, *P. uniformis* and *Sarima* sp. have anything to do with the spike-disease some other indicative symptoms should have been manifested by now, but since none have been presented so far, it would appear that these species have nothing to do with the spike-disease in sandal.

Leaf disease of Sandal under field conditions.—Till about a year ago, the existence of sandal leaf disease was not known. Early in February 1932 I visited the Sanamavu unreserve with a view to select a site for experiment under 1 (*c*) of the entomological programme. Three areas were selected and cleared. While inspecting the sandal trees in one of the areas,

small seedlings, saplings, poles and trees were found to show a leaf disease. An enumeration was made at this site and it was found that in an area of 0.15 of an acre, there were present 966 sandal seedlings, saplings, poles and trees, out of which 324 showed the very leaf disease which was produced by the curculoinoid beetles in the experimental plants. The leaves of the sandal plants were found to be eaten and *S. cretaceus*, *D. sparsus* and *Myllocerus* sp. beetles were seen and collected.

The Sanamavu unreserve is considered to be a disease-free sandal area. It is located near Gopasundiram village in the Sanamavu Forests of the Denkanikota West Range. It is 8 miles by road from Hosur and is situated 18 miles east of Thalli spike area, 14 miles north-north-east of Denkanikota spike area, and 16 miles north of Aiyur spike area.

Qualitative insect collections.—A study of the insect fauna of individual sandal tree and seven of its associated host plants in healthy and spiked areas of the Denkanikota reserve forests has been made. Only the important suspected vectors are mentioned in the report.

Albizzia amara-Sandal.—*Ricania* sp. was present on albizzia only, while *P. uniformis*, *B. indicus*, and *M. lutescens* were entirely absent from albizzia. Aphids were present on sandal but were absent from albizzia. Thrips were found on both sandal and albizzia in the healthy area only. In this group *T. verticalis* and *E. tomentosa* were found to be entirely absent.

Canthium didymum-Sandal.—Exclusive presence of any species on Canthium was not noted, but *Sarima* sp. and *S. cretaceus* were found to be entirely absent from Canthium. Aphids and Thrips occurred on both Canthium and Sandal. In this group, *E. tomentosa* was found to be entirely absent.

Erythroxylon monogynum-Sandal.—*E. tomentosa*, *Ricania* sp. and *S. cretaceus* were present on erythroxylon, while *T. verticalis*, *L. mutica* and aphids were absent from it. Aphids were found on sandal only. In this group *Thysanoptera* (Thrips) were entirely absent.

Lantana camara-Sandal.—*Sarima* sp. was present on lantana only, while *M. variabilis*, *A. walkeri*, *M. lutescens*, *E. tomentosa* and Psyllids were absent from it. Aphids and *Thysanoptera* (Thrips) were present on both lantana and sandal. In this group *L. mutica* and *Ricania* sp. were found to be entirely absent.

Pterolobium indicum-Sandal.—*Thysanoptera* (Thrips) were present on Pterolobium only while *D. sparsus*, *P. uniformis*, *T. verticalis*, *L. mutica* were absent from it. Aphids were found on both sandal and Pterolobium. In this group *S. cretaceus* was found to be entirely absent.

Scutia indica-Sandal.—*E. tomentosa* was present on Scutia only while *B. indicus* was absent from scutia. Aphids and *Thysanoptera* (Thrips) were taken from both scutia and sandal. In this group *L. mutica* was found to be entirely absent.

Zizyphus œnoplia-Sandal.—Exclusive presence of any species on *Zizyphus œnoplia* was not recorded. *T. verticalis*, *B. indicus*, *Ricania* sp., *Thysanoptera* (Thrips) and aphids were found to be entirely absent from Zizyphus and Sandal. A disease similar to sandal-spike is commonly seen on *Z. œnoplia*, and the entire absence of *Thysanoptera* and aphids from this plant is remarkable.

Feed plants of Sandal insects.—From the records so far available it can now be said that amongst the Curculoinoids, *Myllocerus* sp. feeds on sandal, *Albizzia amara*, *Canthium didymum*, *Erythroxylon monogynum*, *Lantana camara*, *Pterolobium indicum*, *Scutia indica* and *Zizyphus œnoplia* ; *Dereodas sparsus* feeds on all the above tree species except *Pterolobium indicum* ; *Sympiezomias cretaceus* feeds on all except *Canthium didymum* and *Pterolobium indicum*. Amongst the sap sucking insects, *Acropona walkeri* feeds and breeds on all except *Lantana camara*, *Sarima* sp. on all except *Canthium didymum* and *Zizyphus œnoplia* and *P. uniformis* on all except *Albizzia amara*, *Pterolobium indicum* and *Zizyphus œnoplia*. Several Psyllids feed and breed on all plants except *Lantana camara*. *Thysanoptera* (Thrips) do so on all except *Erythroxylon monogynum* and *Zizyphus œnoplia*. *Aphididæ* feed and breed on sandal, *Canthium didymum*, *Lantana camara*, *Pterolobium indicum* and *Scutia indica*. *Moonia variabilis* feed and breed on sandal, *Erythroxlyon monogynum*, *Pterolobium indicum* and *Scutia indica* ; *Ricania* sp. does so on sandal, *Pterolobium indicum*, and *Scutia indica*. *Ledra mutica* breeds on sandal and *Albizzia amara*, *Melicharia lutescens* on sandal and *Scutia indica*, *Eurybrachys tomentosa* on sandal and *Zizyphus* and *Tambinia verticalis* on *Canthium didymum* only.

Field notes on *Aphididæ*.—Aphids were collected in the field from the following plants:—beans, cholam, dal (*Cajanus indicus*), horse gram, mustard, pomegranate, rose, *Aegeratum* sp., bamboo, *Cassia auriculata*, *Dodonæa viscosa*, *Flueggia* sp. grass, *Ixora parviflora*, lantana, *Marsdenia* sp., *Physalis* sp. and *Scutia indica*. They were transferred to sandal plants with a view to see if they would take to it.

The results show that most of the aphids survived for only 2—11 days on sandal, but the aphids collected on *Aegeratum* sp., *Ixora parviflora*, lantana and *Scutia indica*, lived for more than 15 days. One batch of the lantana aphid remained alive for 68 days. Transmission experiments with aphids of these plants have been planned. Further field studies would be carried out to locate the alternate food plants of various aphids for breeding and transmission studies.

Life-history studies.—The life-histories of *A. walkeri*, *L. mutica* and *E. tomentosa* have been studied.

N. C. CHATTERJEE.

Entomological Investigations by the Forest Research Institute—II. Work done at Dehra Dun.

Apart from taxonomic and routine work, as indicated in previous reports, detailed analyses of the seasonal incidence and relative abundance of the commoner species in the quantitative collections have been commenced. The data for certain species that have been under consideration as possible vectors is given in the accompanying diagrams. Analyses of certain other species were also made. The main results are noted below :—

Derodus spp. occur throughout the year, but are most abundant from March to June. They have been taken in all the localities, being most common at Aiyur, where spike is not very prevalent. The differences in the number of specimens taken in the various plots are negligible in most cases, but at Aiyur they are most rare in the heavily spiked plot 20 (15 specimens) and most abundant in the spike-free plots, 15, 16 and 21 (72-82 specimens in each). *Derodus* are also commoner in the comparatively healthy area of Kottur (169 specimens) than they are in the heavily spiked areas of Jawalgiri (129 specimens) and Fraserpet (79 specimens).

The green species of *Myllocerus* are very abundant, especially between May and September, at Jawalgiri, common at Aiyur, fairly common at Kottur and very rare at Fraserpet. In Jawalgiri they are conspicuously common in plot 2 (423 specimens) and rare in plot 9 (75 specimens) ; in Aiyur they are most common in plot 18 (361 specimens), least common in plot 16 (102 specimens) ; in Kottur there is little difference in the number of specimens taken in each plot.

The Lycids (*Lycostomus* spp.) are most abundant between May and August at North Salem and only in May at Kottur, being absent or very rare in the other months of the year. They do not occur in the Fraserpet plots. At Jawalgiri some 200 specimens were taken in plot 9, there being less than 25 specimens in each of the other plots. At Aiyur 62 specimens were taken in plot 19 and 12 specimens in plot 20 (both spiked plots), there being less than 5 specimens in each of the other (spike-free) plots. At Kottur between 60 and 70 specimens occurred in plots 23 and 27, 25-35 specimens in plots 24 to 26 and 7-10 specimens in plots 22 and 28.

The figures given here suggest that *Moonia variabilis* is the most probable vector among the species studied. Its abundance decreases as spike-disease becomes less evident, and it is most common for a period (December-February) preceding the months (May-September) when the observed number of newly spiked trees is highest. It is again common in the middle of the spike season, and it could be supposed that this fact is associated with the continuation of the occurrence of newly spiked trees till September and the very high incidence of such trees in June-July (on the assumption that additional infections quicken the manifestation of disease symptoms). It is also very rare in the two

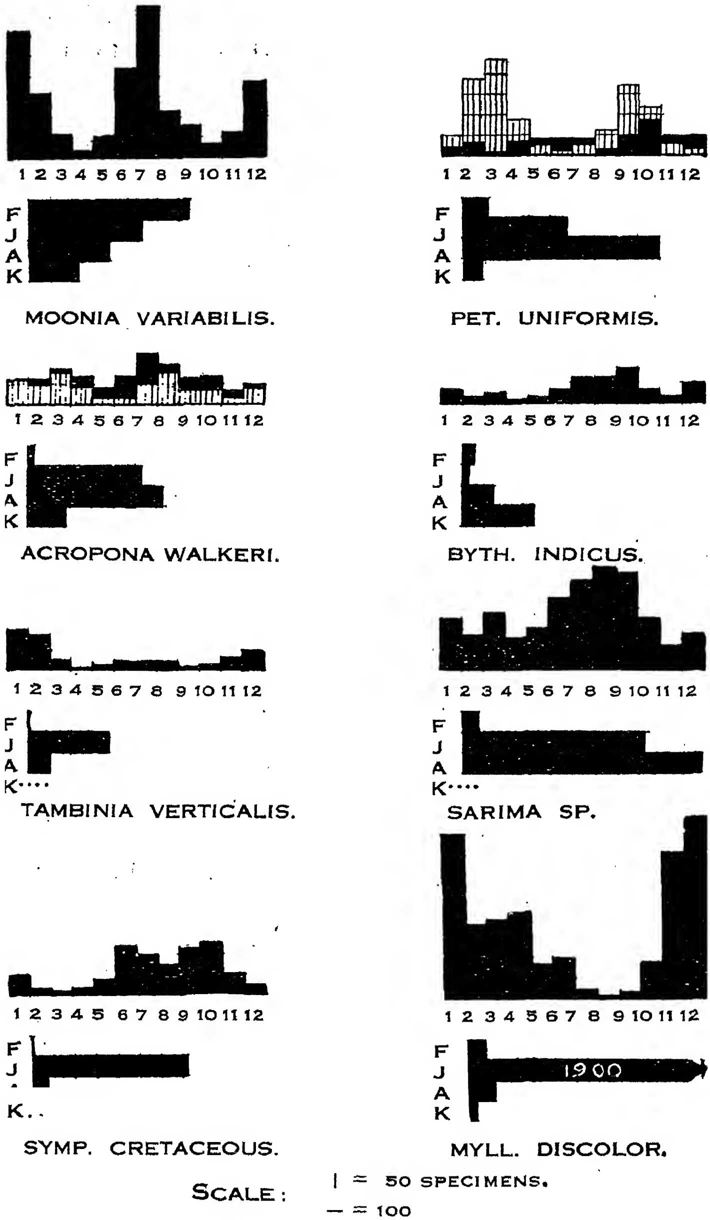

Figure 1. Seasonal Incidence (perpendicular) and Relative Abundance (horizontal) of some Common Sandal Insects. Numbers below perpendicular columns indicate months of the year; letters against horizontal columns are the initials of the localities Fraserpet, Jawalgiri, Aiyur and Kottur respectively. Hatched columns indicate incidence of nymphs.

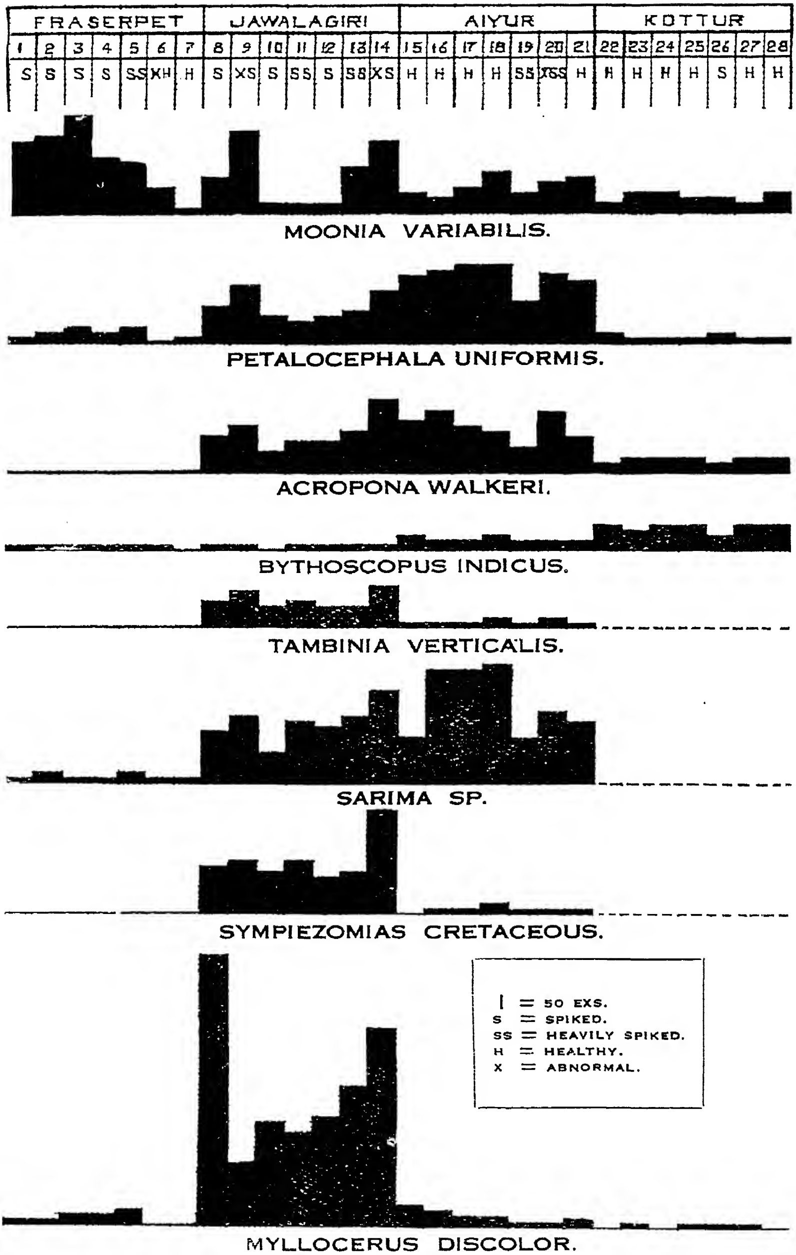

Figure 2. Abundance of some Common Sandal Insects in Sample Plots 1-28. Based on one year's totals.

Fraserpet plots that are spike-free though much more common in the remaining five (spiked plots) than in all the seven plots in each of the other three localities, but the attribution of any particular significance to this fact does not seem justifiable.

The selection of *M. variabilis* is therefore largely dependent on the argument that the vector should be commoner in areas that are heavily spiked than in those where the incidence of the disease is low. There is, however, the converse assumption that the vector may be commoner in comparatively healthy areas where spike is spreading than in areas that are already heavily spiked. On this basis it may be possible to select *Bythoscopus indicus* as a likely vector, but the available data do not permit further comment.

The figures for *Petalocephala uniformis* and *Acropona walkeri* suggest no correlation with spike-disease. In the case of *A. walkeri*, however, it should be remembered that it is one of the *Jassinæ*, to which sub-family all the important Jassid vectors of viroses belong. Species of *Jassinæ* are also significantly associated with the spread of viroses of the 'yellows' group, which includes spike of sandal, according to Quanjer. This may, perhaps, be regarded as an argument against the selection of *M. variabilis* and in favour of the consideration of *A. walkeri*. Other Jassinæ occur, but are inconspicuous and remain to be identified. An analytical study of this group will, however, be available in the near future, on the basis of taxonomic work by Dr. H. S. Pruthi.

The data on the remaining species seem to provide no basis for regarding them as probable vectors, but the possibility of their transmitting the disease is under experimental consideration. The figures for *Lycidæ* are interesting because species of this family occur during the season when sandal is generally in flower. At present, however, we are not in a position to draw any conclusions about the probability of spike-disease being conveyed by pollen transmission through insect agency.

A number of taxonomic reports are now available. These will be referred to in the next report.

CEDRIC DOVER.

768-32 Printed at the Bangalore Press, Mysore Road, Bangalore City.

Working Committee's Review of the Progress Reports.

Three fresh out-breaks of spike have occurred: two in North Salem, one in Coorg. The areas are characterized by fires in the past, proximity of cultivation and an abundance of lantana.

A recrudescence of the disease in an epidemic form has been noticed in the Beedamaruthupatti spike area.

Pollarding which has been carried out on a fairly large scale in Galigattam and Manchi areas has yielded significant data. So far, Manchi has the maximum percentage of disease-masking sandal plants. The entire freedom from infection of a few areas, Sanamavu and Thalli in North Salem and Chickabettakere in Coorg, has been established by pollarding.

Zyzyphus jujuba and *Erythroxylon monogynum* have been found to relatively impart disease-resisting properties to the sandal plant when employed as host plants. Sandal plants nourished by *Acacia suma* and *Butea frondosa* are rendered particularly susceptible to disease.

The rapidity with which the sandal plants in the Kennilworth Castle have succumbed to artificial infection is noteworthy. The average incubation period (the period elapsing between infection and manifestation of disease), which appears to be independent of girth class is 92 days. This information is useful in determining the length of the periods necessary for determining whether a plant is comparatively resistant or particularly susceptible to experimental disease transmissions.

The alarming spread of lantana in North Salem from 3 per cent. in 1917 to 42 per cent. in 1932 and its close relationship with the incidence of spike disease, emphasizes the need for immediate action.

The proprietary tree killer *Atlas* has so far been the most potent arsenical preparation in effectively killing the spiked plants.

A high content of basic nitrogen appears to characterise the factor of susceptibility in sandal plants, while resistance can be correlated with a high content of the mono-amino fraction. Spiked tissues are found to contain 2-3 times more tannin than the healthy one.

The study of the insect fauna of sandal and certain selected hosts, as discussed on page 13 of the report for the quarter ending March 1932, has been continued. It may be noted that coccids and psyllids are commoner in spiked areas than in healthy areas, while the members of jassids taken are similar to both spiked and healthy areas.

Various methods of insect transmission are now in progress but, so far, no positive results have been obtained. *Acropona walkeri*, a Jassid, has been included among the species regarded as probable vectors of spike.

Report on Work done and Observations made by the Madras Forest Department in collaboration with the Indian Institute of Science, Bangalore—I.

Primary attacks of Spike-Disease.—Two cases of primary attack were reported, one in coupe IV Pennagaram sandal series in Guttiroyan R.F., and the other in Kodagarai unreserve. On inspection, the Kodagarai affected area was found to be equally distributed among (1) cultivated fields, (2) Kodagarai unreserve and (3) Kempakerai R.F., which comprises a portion of the western slopes of the Guttiroyan Hill. The entire block affected with the disease is at a distance of 5 miles north of Beedamaruthupatti area spiked since 1928 and at about the same distance east-south-east of Manchi unreserve spiked in 1931. Nearly 120 acres have been affected and the elevation varies from 3,300 to 3,600 feet above sea level.

The jungle is of the high forest type on the slopes and of open scrub type on the plateau interspersed with patches of semi-evergreens. The scrubby open portion appears to have been burnt frequently leaving plenty of dead stumps of trees and bamboos and thick patches of lantana bear testimony to the frequent fires in the past. The stocking of sandal is not very thick but good sized trees are not uncommon. Weeds associated with agricultural operations such as *Malvastrum coromandalianum*, *Sida acuta*, *Achyranthes aspera*, were suffering from mosaics characteristic of other spike areas.

Considering the nature of forest growth and the stage of the disease, the first attack appears to have occurred in October or November 1931 on the slopes of the Kempakerai R.F., and spread upwards.

The coupe IV Pennagaram area is situated within the Guttiroyan R.F. 4 miles to the north of Beedamaruthupatti spike area, 6 miles S.-E. of Manchi area and about a mile S.-E. of Kodagarai unreserve spike area described above. This area is about 50 acres in extent and has an average elevation of 3,600 feet. The forest is of the semi-evergreen type with patches of scrub, which are presumably the result of severe fires in 1929 and lantana has since invaded the area. Stocking of sandal is more than that obtaining in the Kodagarai unreserve and consists of all sizes.

This area lies in close proximity to cultivation and mosaic was found extensively prevalent among the associated weeds. Even *Jatropha curcas* showed leaf curl and crinkling. The stage of the disease points to its having started some time towards the close of 1931.

2. **Spread of Spike in old areas.**—Special mention appears to be called for in respect of an epidemic spread of the disease which was noticed this year in the Beedamaruthupatti spike area in which spike started in 1928. The disease which was more or less confined to the original area till March 1932, has since then spread rapidly in all directions except to the north affecting more than 700 trees as against 900 spiked during the preceding three years and a half. The incidence was largely confined to the open scrubby patches and cultivated fields while in evergreen patches the diseased trees were few and far between. It can be definitely stated that no fires have occurred in the area of spread during the past two seasons.

3. **Pollarding of Sandal Plants.**—This operation was carried out on a fairly large scale in both the Galigattam and Manchi areas and on a limited scale in the Jawalgiri 6-acre regeneration area. All these three are already sipked areas. Similar work was also done in the Sanamavu reserve and in the central portion of Thalli reserve which are spike free. The objects were to (1) force out masked symptoms if any and eradicate possible sources of infection, and (2) determine if a forest situated in close proximity to spiked areas is definitely free from infection. The following table gives the number of trees pollarded and the percentages of disease-masking plants in the area.

Area	No. of trees lopped	Percentage of disease-masking plants
Jawalgiri 6-acre regeneration area ..	75	2·6
Manchi A	307	1·0
Manchi B	5,323	6·3
Galigattam	7,377	0·1
Nyamasandiram	50	10·0
Sanamavu	44	0·0
Thalli	54	0·0
Uduparani	42	0·0

4. **Susceptibility and Disease-Resistance.**—It has been found that under sylvicultural conditions, sandal plants associated with leguminous hosts such as *Cajanus indicus*, *Acacia farnesiana* and *Pongamia glabra* have got spiked while those associated with *Zizyphus jujuba*, *Melia indica*, *Melia azidirach*, *Dodonia viscosa* have continued healthy.

Sandal plants in pots which exhibited autogenic resistance to grafting operations in the Institute of Science have now been planted in severely infected areas of Jawalgiri—the manurial plot and the Bungalow experimental area.

5. **Grafting under controlled conditions.**—Grafting of spike on sandal in association with *Strychnos nuxvomica*, *Zizyphus jujuba* and *Erythroxylon monogynum* and under controlled conditions in pots both at the Institute and at Denkanikota has so far failed, whereas in association with *Acacia suma*, *Albizzia amara* and *Butea frondosa*, it has succeeded in inducing the disease.

Grafting mosaic leaves of *Aegeratum conozoides*, *Sida acuta* and *Malvastrum coromandalianum* on sandal plants in pots has not yielded any results. No organic fusion was effected in any of the cases.

6. **Grafting under Sylvicultural Conditions.**—(*a*) *Kennilworth Castle area.*—Grafting trees of girth classes from 0–1″ upto 15″–16″ was carried out in the perfectly healthy sandal area of Kennilworth Castle with a view to determine:—(*a*) the resistance offered by a given environment to artificial grafts and (*b*) the resistance offered by various girth classes. The results so far obtained indicate (1) the period for the manifestation of the disease is independent of girth class. This was not at all expected because in pot culture experiments the period of manifestation has been directly proportional to the girth class. (2) The average period required for the manifestation of the disease in this area has been very much lower than what has usually been the case in other areas. (3) When compared with Mahadeswarangudi area the apparent immunity enjoyed by the sandal plants in this area is not real. The plants have so far continued healthy due possibly to the accidental circumstance that no viruliferous vectors have migrated to the spot but this does not exclude the possibility of the vectors themselves being present. (4) As contrasted with other areas like the Indian Institute of Science and Mahadeswarangudi, this area is particularly susceptible. (5) The earliest manifestation and the highest percentage have been almost entirely confined to the east and north-east of the area.

(*b*) *Nognoor area.*—Monthly graftings of a definite number of known aged plants were continued in the Nognoor regeneration plot. 4 plants (2 grafted in October 1931, one in February 1932 and 1 in March 1932) were found diseased during the half year. It is to be noted that with the same amount of infected material on similar aged plants, the disease has

manifested itself after different periods, *e.g.*, 100 days (from 3–3–1932 to 10–6–1932), 187 days (from 4–2–1932 to 9–8–1932), 228 days (from 26–10–1931 to 10–6–1932) and 260 days (from 26–10–31 to 2–7–1932). In all cases girdling below the point of manifestation and infection as a means of preventing the virus from circulating throughout the plant has not succeeded but in the base of one plant in Nyamasandiram Agraharam observation area plenty of healthy shoots from below the girdled part have appeared and it is continuing perfectly healthy. Grafting leaves of this latter plant on healthy sandal in pots has not induced the disease even though there was organic fusion.

7. **Lantana and Spike Disease.**—No spike has so far been induced in the Nognoor plot in which lantana obtained from a spiked area was planted. With a view to find out if spike will avoid an area devoid of lantana, a plot of 1 acre in extent has been cleared of all lantana and all sandal were enumerated and are kept under observation. This plot is located in the direction of the present spread of the disease.

The area of lantana-infested forests in North Salem has been worked out and found to be 42 per cent. of the total extent of the reserves in 1932 as against 3 per cent. in 1917. This indicates the rapidity with which this pest is taking possession of our forest areas, and any measure directed towards its control is bound to prove unpractical (due to the prohibitive cost of clearing lantana) unless some effective biological method is invoked to keep down the pest.

Experiments to control this pest and regenerate sandal by the introduction of fast growing species which will form a heavy cover are now in progress.

Experimental plots in which indigenous species were encouraged and allowed to cover the area by artificial elimination of lantana are not free from spike but the incidence is less. In this plot, spike existed even before the lantana was removed.

The following is the percentage of incidence in the different plots of Cairn No. 53 and Nyamasandiram Agraharam observation area for the half year ending 30th September 1932:—

	Cairn No. 53	Nyamasandiram area
Control	10·49	33·5
Lantana cleared and spike left	5·58	4·4
Lantana cleared and spike cleared	Nil	2·61
Lantana and spike cleared	6·79	1·33
Spike removed and lantana left	..	7·51

In spite of presumable exposure to virulent natural infection on plants raised either naturally or artificially on the forest floor in the Jawalgiri R. F. no plant in pots or drums kept scattered over the area has so far been naturally infected.

Among the platform plants kept in Samayeri except the one already reported, no more have shown the disease.

With a view to find out if healthy plants in a severely spiked area could be protected by continued caging, 115 plants have been selected in the 6-acre Regeneration plot at Jawalgiri and caged in March and April 1932. They have been found free from masked infection and they have been subjected to fumigations with hydrocyanic acid and chloropicrin.

8. **Manurial plot.**—Another dose of manure was given to these plots at Aiyur and its effect on the spread of natural infection is awaited. The percentage of monthly incidence in these plots is tabulated below :—

April—nil; May—1·9; June—1·6; July—nil; August—0·9; and September—nil.

9. **Soil Profile Studies.**—These were extended to various spiked and healthy areas during the half year and results are tabulated below :—

Locality	Nature of the area	Humus layer	Average lowest depth to which any root had penetrated	Number of roots ½″ and above in diam. found in the profile
Devarabetta	Healthy	11″	60″	23
Do.	Spike	6″	43½″	22
Sanamavu	Healthy	14½″	54″	22
Aiyur	Healthy	13½″	46½″	22
Do.	Spike (Manurial plot)	4½″	28″	8*
Mahadeswaran-gudi	Resistant area	8″	22″	14
Gulhatti	Spike	12¼″	30″	21

* 2 profiles only are taken as the remaining are not yet sketched.

It is to be noted that Gulhatti R. F. was once a very thickly stocked sandal area. It was affected by the disease in the year 1917. Since then heavy exploitation of spiked trees was carried out till 1926. The regeneration of sandal is profuse; the area is well clothed with vegetation and patches of semi-evergreens are not wanting. The soil profiles in this area, however, showed, that the roots of hosts in general had not penetrated below 18″ irrespective of soil conditions which varied from place to place.

Profiles close to two big sized sandal trees in Gulhatti R. F. (healthy sandal girth 28″ and spiked sandal girth 23″) were examined. In the case of the healthy sandal, its roots had penetrated upto a depth of 6 ft. whereas in the case of spiked sandal the penetration was only upto 2 ft.

10. **Attempts to isolate a resistant strain of Sandal.**—The plants raised from seeds of healthy sandal trees of old spike areas continued healthy for 7 years and then got spiked. This indicates that although parent trees might remain unspiked for many years while all their neighbours have died of the disease, they do not necessarily produce seeds whose plants remain permanently immune.

11. **Do plants get infected when under cover ?**—In accordance with the suggestion of Rao Bahadur K. R. Venkatramana Ayyar, plants under bushes were selected and pruned with a view to force out masked infection, if any. In all cases, the primary shoots have come up healthy and the development of secondary shoots is awaited. Similar plants from same locality have also been uprooted and stumped in pots.

A. M. C. LITTLEWOOD.
S. RANGASWAMI.
M. SREENIVASAYA.

Experiments conducted by the Madras Forest Department in collaboration with the Indian Institute of Science—II.

Field Experiments.—*Experiments on the eradication of spike through the application of chemical agents.*—The method consists in girdling the tree at its base by removal of the bark, exposing the woody portion and subsequently smearing it with the solution. Among the various solutions tried, the patented 'Atlas' tree killer is the most efficient, the criterion of efficiency being the effective killing of the diseased plant within a period of three weeks. The success of this treatment is conditioned chiefly by the weather, the penetration of the active principle 'Arsenic' to reach the roots being quicker in the hot season, while in the wet periods, it takes a much longer time. Other arsenical solutions containing arsenic in much less proportion than the 'Atlas' solution, were prepared in the laboratory both from caustic soda and white arsenic and from sodium arsenite crystals with strong alkali (KOH) added. These substitutes contain about 2 lbs. of arsenious oxide per gallon while 'Atlas' has 5 lbs. This dilution is probably responsible for the ineffective results. Stronger

solutions will next be tried. Potassium arsenite appears to be more effective than the corresponding sodium salt.

The method of boring holes into the tree and bunging with chemicals such as sodium chloride, copper sulphate, potassium chlorate and *p*-dichloro-benzene has not led to encouraging results.

The root-system of the treated plants does not appear to be affected in many cases except with 'Atlas' where a large number have been successfully killed. In the case of Atlas-treated plants, root-suckers also are found to be dead. Coppiced stumps are effectively killed by Atlas.

Lantana and Spike.—In view of the close relationship of lantana to spike incidence, its eradication seems desirable. In consultation with Mr. A. M. C. Littlewood, District Forest Officer, North Salem, a plan has been drawn up in pursuance of the resolution of the last Annual Spike Conference.

Field Observation.—In continuation of what has been recorded before, it has been noticed latterly that the white blotches noticed on the leaves in the Sanamavu R. F., have disappeared and the plants have put on healthy growth. Plants in Denkanikota pot culture house were grafted with these blotched leaves and the operated stock is continuing healthy.

S. RANGASWAMI.
A. V. VARADARAJA IYENGAR.

Experiments in Coorg.

The following programme was drawn up by Mr. Sreenivasaya in consultation with the Chief Forest Officer, Coorg, in June last and progress has been made as detailed below.

1. Quantitative recording of the flora of each significant patch in the manurial plots at Chinnanhalli with a view to ascertaining the absence or dominance of a particular combination of species which might explain the immunity to disease exhibited by certain sandal plants in the area.

This quantitative recording of the flora has been carried out in 9 significant patches both good and bad and in addition soil profile studies in 6 pits dug in 6 different patches have also been carried out.

In order to force out "masked" symptoms, 404 healthy sandal trees were pollarded. In addition, 1,685 spiked sandal trees in and within 50 ft. of the plots were uprooted and removed from the area.

It is too early to say definitely whether any of these pollarded trees show signs of the disease, but the appearance of 45 out of the 404

pollarded trees is suspicious. Before pollarding, the available seed was collected from the trees and sent to the Indian Institute of Science for morphological examination of the seed with particular reference to the number of ribs.

2. **Manurial plots at Chikkabettakeri.**—Pollarding of the plants in this area has not forced out any symptoms of disease; only periodical inspections of the area will be carried out. Seed when available will be collected from a few typical trees and sent to Bangalore.

3. **Ecological Survey.**—The Doddamolthe sandal area 3 miles north of Somwarpet, which is completely healthy, was selected and the area divided into 20 strips. Soil profile studies were carried out in 6 places in addition to the quantitative recording of the flora in a few strips.

4. **Study of Scars.**—Sandal twigs containing scars were collected from different centres in North Coorg and sent to Bangalore for examination and classification there.

5. **Seed Selection and Testing.**—Nothing could be done in this direction, as seed was not available during the period.

Fresh Outbreaks of Spike noticed.—A solitary case of spike was noticed early in September by Range Officer U. K. Thimmayya, on the Somwarpet-Kodlipet Road near the 34th mile stone. Up till now the nearest spiked tree was 2 miles to the north-east.

There are about 75 sandal trees growing round the old Fraserpet Fort, which appear to have shown no signs of disease for the last 10 or 15 years. Since last June, about 30 trees have been attacked, and in other places there is evidence of the attack of spike disease being particularly virulent this year, several new outbreaks being reported.

Past history of the old plantations and spiked areas as far as possible was collected from the Range Records and sent to the Indian Institute of Science, Bangalore.

The statistical data relating to the quantitative surveys and plans of the areas have been sent to Bangalore along with the report.

H. G. HICKS.

Experiments conducted by the Indian Institute of Science. Laboratory Experiments—I.

Studies in the Resistance of Sandal Plants to Spike Disease.

It has been experimentally proved both under laboratory and sylvicultural conditions that certain type of host plants like *Acacia farnesiana* and *Pongamia glabra* render sandal susceptible to disease while host plants of the type Margosa, *M. koenegri*, render sandal resistant to disease. The chemical factors which influence susceptibility and resistance to disease have now been investigated with particular reference to the nitrogenous constituents.

Experiments have been carried out on the distribution of main nitrogenous constituents in the leaves of sandal in association with different host plants.

The results have been tabulated below :—

TABLE I.

Form of Nitrogen in Sandal Leaves	Associated Host Plants				
	Morrya koenegri	*Acacia farnesiana*	*Melia indica*	*Rutea graveolens*	*Dendrocalmus strictus*
Amide	..	3·56	7·40	3·57	5·04
Total Basic Nitrogen	6·40	16·78	10·96	14·28	21·83
Total Non-basic Nitrogen ..	90·00	70·00	79·83	70·75	63.30

Results are expressed on per cent. total water soluble nitrogen.

It will be seen from table I that susceptible sandal plants nourished by hosts like *Acacia farnesiana* are characterized by a high-content of basic nitrogen while those fed by hosts like *Melia indica*, *Rutea graveolens*, contain a high percentage of the non-basic fraction.

A detailed analysis of the nature of basic and non-basic fractions is in progress, which, we hope, will throw more light on the nature of susceptibility and resistance of sandal to spike disease.

Y. V. SREENIVASA RAO.

Experiments conducted by the Indian Institute of Science. Laboratory Experiments—II.

The experiments reported in the last quarterly report were continued during the present half year.

1. **Physiologicial factors of disease resistance.**—(*a*) *Organic acids.*—In continuation of what was reported last, the esters fractionated were weighed and utilized for the dihydrazide preparations, by means of which, the identifications were sought to be carried out. The preparations of these derivatives involved considerable trouble and finally were successfully made. The crude products so obtained were purified, recrystallized and their melting points determined and further checked by the mixed melting points with pure substances many of which were also prepared. Combustions were also carried out with particular reference to the nitrogen content.

(*b*) *Tannins.*—Tannin content of the diseased and healthy leaves was made by adopting the procedure described below. The dried materials were extracted with ether to remove gallic acid and the residue extracted with alcohol. The alcoholic extract was precipitated with lead acetate and the precipitate centrifuged and washed and treated with minimum amount of sulphuric acid. The solution thus obtained was utilized for the tannin estimation, colorimetrically with standard tannin similarly treated. It was found that the spiked tissues contained 2—3 times more tannin than the healthy ones, irrespective of the season. Moreover, the colour reaction in the diseased leaf extracts was different from the normal extracts towards various reagents.

A more detailed study of the tannins is in progress.

(*c*) *Other buffering principles of plant saps.*—It was pointed out in the previous report that the spiked leaf tissues have a higher phosphorus content. By adopting Embden's method it was found that the tissue fluids of spiked leaves contained a greater quantity of phosphorus than the healthy ones volume for volume. In the diseased specimens, phosphorus has been examined and found to exist chiefly in the inorganic form, the organic form, chiefly as phosphatides accounting for about 35 per cent. of the total phosphorus. On the other hand, in the healthy ones, the quantity of phosphorus in the organic form is nearly 60 per cent. of the total, so much so that the inorganic form of phosphorus is significantly low. Titration experiments are now in progress to elucidate the rôle of phosphorus as the buffering agent in the leaf sap of sandal.

2. **Analysis of 'Atlas' treated plants.**—Spiked sandal plants killed with 'Atlas' were analysed for their oil and arsenic contents. It was found,

as a result of the several analyses, that the oil content of the heartwood varies and in some cases the heartwood contains arsenic in very small quantities ranging from 0.00002–0.00006 per cent. No arsenic could be detected in the oil derived by the solvent method. Experiments to determine if any arsenic is carried over along with the oil during steam distillation are now in progress.

A. V. VARADARAJA IYENGAR.

Entomological Investigations by the Forest Research Institute—I.

Work done at the Indian Institute of Science.

In April and May Mr. Chatterjee's time was largely occupied by routine and field work. No transmission experiments were conducted, but observations on those previously started were continued. All experiments commenced prior to May 28th were concluded in the period under review, no positive results having been obtained after prolonged observation and pruning. Of these experiments, 41 were concerned with transmission by suctorial insects (*Moonia*, *Petalocephala*, *Sarima* and Aphids), and 35 with transmission by mandibulate insects *Sympiezomias*, *Dereodus* and *Myllocerus*). In the latter case Mr. Chatterjee has stated that the experiments had given evidence of transmission of a leaf-disease ("chlorosis") of sandal. All the affected plants were pruned in June, the new flush, however, being quite healthy. Mr. Chatterjee also conducted some 32 transmission experiments in sleeves, chiefly using the species noted above. These have been concluded with negative results.

Since June, the programme of work at Bangalore has been remodelled, attention being concentrated on the provision of definite evidence of insect transmission or otherwise. An attempt was made to ensure a regular supply of insects for experimental purposes by stocking two large cages with plants and releasing in them the results of daily collections of insects. In spite of successful breeding, we have not, however, succeeded in raising the insect population to its optimum, on account of the heavy demands made on the cage and the inadequacy of the daily collections. The present population of these two cages is about twenty thousand, but we hope to raise the number to one hundred thousand in the near future.

These stock cages are also intended to serve as mass transmission experiments on a large scale, since both spiked and healthy plants are present in the cages. Unfortunately, however, the number of spiked plants available for these cages is very small: 16 against 160 healthy

sandal, 6 lantana and 3 Zizyphus. With the co-operation of Mr. Sreenivasaya, it is hoped that the ratio will be increased before-long. The majority of the heathy plants in these cages were pruned three months after introduction. The new flush is quite healthy.

To narrow down the enquiry, experiments were conducted with small groups of insects (*Jassids*, *Fulgorids*, *Curculionids*, *Aphids*, *Psyllids* and *Thrips*, mixed *Hemiptera* and *Curculionidæ*, *Chrysomelids* and *Grasshoppers*) released after a "spike-feed" in cages containing a spiked and a healthy sandal plant. One series of experiments has been concluded with negative results, and another is in progress. Arrangements have been made for sufficient additional cages to carry out such experiments on larger scale.

In addition to the above work, 32 experiments with individual species, thought to be possible vectors on the basis of previous work, have been conducted. More experiments of this nature were not possible on account of shortage of material. The procedure followed involves a "spike-feed" (30-50 specimens of a species) for five days, release in a cylindrical cage containing a healthy sandal plant, complete pruning of the plant after the death of the insects, or partial pruning after two months if the insects are still alive, the experiment being concluded after the death of the insects and the appearance of the new flush. In variants of this procedure adult "spike-fed" insects have been caged with manually defoliated plants to ensure feeding on the stem, which is thought to be the most susceptible region. In the case of Lantana Aphids, they were given an intermediate feed on lantana before caging with sandal.

The species employed in these experiments are: *Moonia variabilis*, *Petalocephala uniformis*, *Bythoscopus indicus*, *Acropona walkeri*, *Idiocerus clypealis* (Jassidæ); *Sarima nigroclypeata*, *Eurybrachys tomentosa*, *Melicharia lutescens* (Fulgoridæ); *Plautia fimbriata*, *Agnoscelis nubila*, *Nezara viridula*, *Coptosoma cribraria* (Pentatomidæ); *Otinotus oneratus* (Membracidæ); *Monophlebus* sp. (Coccidæ); miscellaneous Aphids; *Sympiezomias cretaceous*, *Dereodus sparsus*, *Myllocerus* sp. (Curculionidæ). The results of these experiments are awaited.

A similar set of 19 experiments, using the species noted above, was started in sleeves attached to ground plants in the garden of the Insectary. The plants have been pruned. Results are awaited. Sleeve experiments (24) were also conducted at Denkanikota, but unfortunately the assistant in charge (Mr. K. Narayana) reports that the sleeves have all been stolen.

An intensified form of specific vector experiment has been conducted with *Moonia variabilis*. Frequent collections of this species are released in a cage containing two spiked plants and four healthy plants, the object being to raise the population in the cage to its optimum (as

evidenced by the condition of the plants), when the healthy plants will be pruned. On the suggestion of the Working Committee, two healthy plants have been removed and replaced by two spiked plants. This experiment will be repeated with *Acropona walkeri* and other probable vectors.

An experiment with flower feeding insects (*Lycostomus præstus*; Lycidæ) has been started, the technique being to release "spike-fed" Lycids in a completely caged, flowering sandal plant growing in the garden attached to the Insectary. Results are awaited.

Field work has been practically confined to the continuation (by Mr. K. Narayana) of the group collections started by Mr. Chatterjee (completed on September 30th), and the collection of material for the stock cages. Collections were made for a short period at Devarabetta, where sharply defined floristic differences are correlated with the incidence of spike, but the results were not significant. Periodic collections were made on sandal in the grounds of the Indian Institute of Science, where no sandal trees have become naturally spiked during several years, in spite of the presence of a large number of spiked plants. These collections revealed a complete absence of *Acropona walkeri* which, by general inference (Dover, *Ind. For. Rec.*, xvii, 1932, p. 46; and *Quart. Rep.*, 1932, p. 18) is thought to be a probable vector of spike disease. In collections made by Mr. P. K. Aiyyappa at Kennilworth Castle (where "natural spike" does not occur, though the area has been shown to be highly susceptible by Mr. Sreenivasaya's work) for forty hours, only two specimens of this species were present, both of them having been taken in an area where spike has not appeared as the result of grafting. No theory is based on these facts, but *Acropona walkeri* has been marked for special experimental attention.

Bionomic work has been restricted to life-histories of possible vectors, studies of seven species (Jassids and Fulgorids) being completed during the period under report. Diagrammatic summaries of their life-cycles with relevant notes and specimens have been sent to the Forest Entomologist for the use of Mr. Chatterjee. Five species (Fulgorids and Curculionids) are still under study.

The raising of plant material for experimental purposes, from seed and by transplanting, has received attention, 96 pots being now occupied.

M. APPANNA.
CEDRIC DOVER.

Entomological Investigations by the Forest Research Institute—II.

Work done at Dehra Dun.

Qualitative insect collections.—Fourteen groups of ten each of one host and one sandal, growing side by side and distributed equally in spike and healthy area were selected in Denkanikota Reserve Forests. They include seven of the commonly occurring associates of sandal, and collections were made daily on a series of fifteen hosts and fifteen sandal, by giving five beats uniformly on each host and sandal. The collections obtained from sandal and its host were kept separately.

The study of the collections has established the specificity of association of certain species of insects with certain host-sandal combination. In this report results based on the study of seven months' collections, comprising over 5,000 units beginning from October 1931 are given and only the suspected species or groups of insect vectors, that may probably be responsible for the spread of the spike disease in sandal are mentioned. The total number of insects collected on sandal and hosts in spike area is 8,332 as against 7,729 in healthy area.

Taking into consideration the relative abundance of species of different families, in percentages of the total *Homoptera* collected, which includes the major portion of all the known specific vectors of virus diseases, it is found that the percentage incidence of *Fulgoridæ* is higher in spiked area than in healthy area, while that of the *Jassidæ* is equally distributed. The families *Cicadidæ*, *Cercopidæ*, and *Membracidæ* are not considered for the present as no member of these families of insects is known to be a vector of virus disease. The percentage incidence of *Coccidæ*, *Psyllidæ* and *Aphididæ* is also found to be much higher in spiked areas than in the healthy areas. No examples of *Aleyrodidæ* have been taken and the species of *Coccidæ* obtained restrict their consideration in the spread of spike for the present.

Further analyses of the *Homoptera*, *Thysanoptera* and *Curculionidæ* have been made and the frequency in numbers of the different species or members of different families of insects is represented in the table below in percentages of the total: Aphididæ 137, Psyllidæ 98, Thysanoptera 41, Jassidæ 690, Fulgoridæ 235, and Curculionidæ 620, collected in the different host-sandal combinations.

Much useful information can be obtained from figures in the table which may profitably be utilized in regulating future work. Some of the salient points are here brought forward. Aphids occur more in spiked areas than in healthy areas and are found both on sandal and the majority of associated hosts studied so far. They are abundant on

Scutia 51%. The *Psyllids* are more abundant on *Zizyphus*-sandal 25%, less so on *Canthium*-sandal 15%, while the *Thrips* are relatively more abundant on *Canthium*-sandal 17%. The entire absence of *Aphids* and *Thrips* on *Zizyphus*-sandal may be noted. The presence of Lantana in sandal forests is believed by various workers to be a contributory factor in the spread of the spike disease. In this connection the entire absence of *Moonia variabilis*, *Ledra mutica* and also of the Jassinæ, *Acropona walkeri* on lantana may be worthy of note. Of the *Curculionidæ*, it will be seen that *Myllocerus* sp. is abundant on *Pterolobium*-sandal 89%, Lantana-sandal 57% and *Zizyphus*-sandal 40%.

A further detailed study of the entire fauna of the different group combinations is in progress with the assistance of the systematic Entomologist's Staff and would be made available in the next report.

Fauna of sample plots.—Analyses of the fauna of the Kottur (Yellagiri) sample plots have also been taken up and studies are in progress.

Further note on Aphididae—Of the Aphids the notorious vectors of virus diseases belong to the genera Aphis, Macrosiphium and Myzias. Aphids collected in the field on sandal have been identified by Dr. C. J. George, to whom my thanks are due, as Macrosiphium, sp. It is suggested that further laboratory work should be concentrated in locating the alternate food plants of the sandal Aphid *Macrosiphium* sp. for rearing and transmission experiments.

Laboratory Work.—A paper on the life-history and binomics of *Sarima nigroclypeata* Mel, a sandal Fulgorid, has been written for publication.

N. C. CHATTERJEE.

Figures represent percentage of the total. H = Healthy area, S = Spike area.

COMBINATION	*Aphididae*		*Psyllidae*		*Thrips*		*Moonia variabilis*		*Petalocephala uniformis*		*Acropona prasina*		*Ledra mutica*		*Rythoscopus indicus*		*Sarima nigroclypeata*		*Eurybrachys tomentosa*		*Melicharia lutescens*		*Tambinia verticalis*		*Ricania fenestrata*		*Dereodus sparsus*		*Dereodus cretaceus*		*Myllocerus* sp.	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
Albizzia	0	0	0	7	7	3	7	7	0	0	14	31	14	10	0	0	7	10	0	0	0	0	0	0	14	0	21	14	0	7	14	10
Sandal	8	0	15	8	3	0	13	21	5	5	28	22	3	4	3	8	13	19	0	0	3	2	0	0	0	0	8	9	0	0	3	4
Canthium	0	15	15	3	15	8	5	5	2	3	24	23	0	2	0	15	0	0	0	0	0	5	22	16	0	3	2	0	0	0	15	2
Sandal	0	5	10	15	17	5	20	14	10	8	10	27	2	3	12	8	0	6	0	0	0	2	7	0	2	3	10	3	0	0	0	2
Erythroxylin	0	0	4	3	0	0	25	29	0	1	20	20	0	0	20	0	6	29	1	0	0	1	0	0	1	0	2	0	0	1	20	7
Sandal	0	1	6	6	0	0	22	29	6	2	32	30	1	1	6	7	17	17	0	0	1	0	2	1	0	0	4	1	0	0	3	4
Lantana	17	8	0	0	0	3	0	0	25	0	0	0	0	0	0	3	45	8	0	0	0	0	0	5	0	0	4	3	0	14	8	57
Sandal	0	21	9	3	2	0	30	5	7	5	30	13	0	0	13	11	0	0	0	3	2	3	0	5	0	0	7	3	0	16	0	13
Pterolobium	0	1	2	2	0	1	2	1	0	0	1	2	0	0	3	1	2	3	0	0	1	0	0	0	0	1	0	0	0	0	89	89
Sandal	0	1	6	5	0	0	22	18	6	8	8	14	0	4	6	0	10	15	0	0	4	3	2	1	0	3	6	11	0	0	29	18
Scutia	40	51	1	0	7	2	7	6	3	1	10	10	0	0	0	0	4	14	1	1	0	2	7	0	1	3	3	1	2	0	10	10
Sandal	7	6	7	10	2	5	13	15	7	2	26	26	0	0	4	7	11	12	0	0	4	5	6	0	2	1	7	7	2	1	2	2
Zizyphus	0	0	17	25	0	0	3	0	0	0	10	17	0	0	0	0	14	0	3	8	0	0	0	0	0	0	10	17	3	8	40	25
Sandal	0	0	12	11	0	0	18	7	12	7	21	32	3	4	0	0	12	21	3	0	3	4	0	0	0	0	9	11	3	4	6	0

2272-32 Printed at the Bangalore Press, Mysore Road, Bangalore City.

Working Committee's Review of the Progress Reports for the half-year ending 31st March 1933.

1. There have been no primary attacks of disease during the half-year under review; in areas already affected, however, the spread has been virulent in North Salem. In a few cases the number of spiked plants have increased five-fold.

In Coorg three stray cases of spike are reported but these have occurred in comparatively close proximity to spike area.

2. Lopping of sandal plants, carried out during last half-year in newly spiked areas, has proved successful in bringing out the masked symptoms of disease. The disease has not spread beyond the demarcated areas.

3. The plants found resistant to experimental transmissions, and planted in the heavily infected areas at Javalgiri are continuing healthy.

4. Grafting of sandal with mosaic affected leaves and spike-like growths of a number of species associated with sandal, has not yielded any positive results, thus suggesting that these diseases have no relation to spike disease.

5. The second series of grafting experiments, carried out in the Kenilworth Castle area, has shown the influence of season in the susceptibility of sandal plants and in the spread of disease.

6. In connection with the last-named item of work an interesting case of a root sucker becoming spiked before the (grafted) parent tree manifested the disease, has been noted.

7. The longest incubation period under field conditions, with artificially infected plants, is 671 days.

8. Two of the sandal plants transplanted in big drums and kept distributed in the heavily spiked area at Javalgiri, have become spiked.

Among the platform plants kept in Javalgiri, five have exhibited the disease including the one already reported. These two sets of

2272-32 Printed at the Bangalore Press, Mysore Road, Bangalore City

Report of Work done and Observations made by the Madras Forest Department in collaboration with the Indian Institute of Science—I.

I. Primary attacks and spread of spike in old areas.—No fresh occurrence has been reported during the half-year but in areas where spike has already started, the spread has been considerable.

(i) In Noganur R.F., only about 300 acres, had been affected till the end of July 1932 but since then the spread is over 700 acres.

(ii) In Kodagarai unreserve and coupe IV Pennagaram only 100 and 60 spiked trees respectively were enumerated up to 22-7-1932, whereas by the end of February 1933 the corresponding figures were 416 and 319.

(iii) In Kempakarai R.F., only 2 trees were observed to be spiked in January 1932 and these were immediately killed with *Atlas*. Since then 21 trees distributed over an area of about 20 acres, have been marked.

In Galigattam, Manchi and Denkanikota R.F.'s, in which lopping and 'Atlassing' operations have been carried out, the disease has not proceeded beyond the demarcated area.

II. Lopping of sandal plants.—In the preceding half-yearly report the word "pollarding" was used to indicate the work we were doing. Since that work merely consisted of the lopping off of branchlets and foliage to induce fresh vegetative activity, "Lopping" would have been the more correct term.

One of the outstanding results of experimental work, so far conducted, has been the fact that plants that have been artificially infected with spike, even though they do not themselves exhibit the outward signs of the disease, can nevertheless be used as scions for infecting other plants, and it is on the basis of that result that lopping of healthy trees in *newly* infected areas has been done with a view to eradicating the masked sources of infection. The lopping of healthy trees around such as show signs of spike in a new area, is thus the most potent known method of preventing the spread of the disease.

Experimental evidence is also forthcoming to show that in individuals in which infection is of very recent origin, the removal of the infected part prevents spread within that particular individual.

The work undertaken has two definite objects, *viz.*,

(*a*) The removal of masked sources of infection, and

(*b*) the saving of a certain number of individuals.

In newly infected areas treated on the above principles to date, the following is the percentage of trees and plants which have manifested the disease:—

Locality	Percentage of lopped trees that manifested the disease
Manchi "A" part	5·5
Manchi "B" part	9·6
Galigattam R.F.	5·6
Denkanikota R.F.	0·9
Kempakarai C. I & II	3·7

All trees that manifested the disease have been killed by girdling and treating with Atlas.

Lopping a few trees, usually not more than 25, was resorted to in healthy areas intervening between spiked localities with a view to ascertaining whether they are really healthy or not; such operations were done in the healthy parts of Thalli and Sanamavu R.F.'s, and have proved that the areas continue perfectly healthy.

III. Susceptibility and disease resistance.—In the Javalgiri mound plot, sandal plants in association with *Dalbergia sissu*, Lantana, *Acacia farnesiana*, *Pongamia glabra*, *Melia azadirach*, *Aristolochia indica*, *Mundolea suberosa*, *Albizzia amara*, *Cajanus indicus*, *Terminalia arjuna*, were found diseased. This has further established the results of pot-culture experiments that lantana, *Acacia farnesiana*, *Cajanus indicus*, *Pongamia glabra* and *Terminalia arjuna* are definitely unsuitable hosts. *Aristolochia indica*, *Melia azadirach*, *Mundolea suberosa*, also appear to be undesirable hosts, even though grafting in pot-culture work has not yet given any definite results.

The plants which exhibited autogenic resistance in pot-cultures and planted in the spike experimental areas of Javalgiri Bungalow and Cairn No. 53 are so far continuing healthy. Those planted in healthy area of Sanamavu R.F. as controls are also coming up well.

IV. Grafting under controlled conditions.—(*a*) Grafting mosaic and other diseased leaves of the following species on sandal has not induced spike:—

Mosaic leaves of *Aegeratum conozoides*, *Sida acuta*, *Malvastrum coromandalium*, *Jatropha curcas*, *Leucas aspera* and spike like growths of *Crotolaria pulcherrima*, *Albizzia lebbek*, *Zizyphus œnoplia*, *Argemone moxicana*, *Stachytarpeta indica*, *Dodonea viscosa* were used as grafting material. Organic fusion did not take place in any of the cases.

(*b*) Insect scars were found to be prevalent on apparently healthy trees in a spike area. With a view to see whether they have anything to do with spike, such scars from apparently healthy sandal plants have been brought from the Aiyur manurial and Javalgiri 6 acre plots and grafted on to potted sandal plants in the Denkanikota Pot-Culture area as well as in the Indian Institute of Science.

At Denkanikota, the patches did not fuse in most of the cases; and in the case of 8 plants only one patch has fused. These plants are so far continuing healthy.

V. Grafting under Sylvicultural conditions.—(*a*) *Semi-evergreen forests.*—The Kenilworth Castle grafting experiments were extended to the semi-evergreen forests of Samayeri, Pane and Thalli, to determine the influences of season on infection and manifestation and to ascertain the rate of spread of infection under different environments—100 plants in each area were selected of which 30 were grafted; each plant received 4 patches and 4 leaves in September and October 1932. In the Thalli area, instead of taking all 50 in one locality as was done in Samayeri, Kenilworth Castle and Pane, 50 in the predisposed area and 50 in the perfectly healthy area were selected of which 25 in each locality were operated on.

In Samayeri and Pane R.F.'s fusion of grafts took place only in a few cases and none of the trees has so far succumbed to the disease, whereas in the Thalli predisposed area 3 out of 17 which took the grafts have got the disease and in the Kenilworth Castle area in which the disease very virulently spread among trees grafted in the months of May and June 1932, only one out of 35 has been affected. This indicates that the season of infection plays an important part in the spread of the disease.

(*b*) In the Kenilworth Castle area, certain interesting observations were recorded:—(i) In one case in which the grafted tree did not manifest the disease, its root sucker at a distance of 70 ft. got spiked and in another a similar result was obtained at a distance of 20 ft. (ii) Several root-suckers of trees which got the disease as a result of grafting have also succumbed more or less at the same time as the parent trees. (iii) Girdling below the point of graft in the case of trees that

were masking the disease has yielded indefinite results in this area in as much as 10 trees out of 94 have shown the disease below the girdled part.

(c) *Noganur healthy area.*—Monthly grafting under sylvicultural conditions :—

Serial No.	Tree No.	Date of grafting	Date of manifestation	Period
1	6	23-12—1930	2-11—1932	671 days
2	131	3—3—1932	24—9—1932	205 ,,
3	148	18—5—1932	12-10—1932	147 ,,
4	87	24—9—1931	14-12—1932	447 ,,
5	211	24—9—1931	do.	do.
6	272	4—9—1932	do.	101 days
7	241	7—4—1932	do.	251 ,,
8	197	4—9—1932	22—1—1933	140 ,,
9	200	do.	do.	do.

The longest period during which the disease has been masked under field conditions is 671 days and material derived in the months of March, April, May and September have so far been infective. As the period of masking also depends on the ecological make up of the plant and as the season of infection appears to play an important part in manifestation, no definite conclusions can be drawn until results are complete.

(d) *Mahadeswarangudi Observation area.*—During the half-year, only 2 of the old trees grafted with 4 patches on 10-10-1931 and one among the 27 new trees grafted on 25-4-1931 were found spiked—the first two after 390 days and the 3rd after 551 days. 3 root suckers of one of the above old trees which exhibited the disease on grafting, have also manifested the disease.

VI. Lantana and spike disease.—(*a*) No spike has so far been noticed in the Noganur lantana plot, in which lantana from a spiked area was introduced.

(*b*) In the one acre lantana cleared plot of Aiyur, spike at first appeared outside the plot in October 1932, and in March 1933 two diseased plants were found inside the plot, *i.e.*, 9 months after the plot was cleared of lantana. These have been uprooted.

(*c*) The following is the percentage of incidence in the different plots of Cairn No. 53 and Nyamasandiram Agraharam Observation area since their inception :—

	Cairn No. 53	Nyamasandiram area
Control	10·5	37·28
Lantana cleared and spike left ..	5·58	7·35
Lantana cleared and spike cleared .	0·70 Old plot	4·35 Both old plots
Lantana and spike cleared ..	7·2 New plot	2·51 Both old plots
Spike removed and lantana left ..	(No plot)	7·51

VII. Natural infection.—(i) Six sandal plants transplanted into big drums filled with soil were put in different places on 16-10-1931 in the heavily spiked area of Javalgiri R.F. One plant got the disease on 13-1-1933 and another on 18-3-1933. The first one is with a leguminous host (*Acacia farnesiana*) and the second one with *Dodonea viscosa* which has hitherto proved to impart resistance in all our experiments.

(ii) Among the platform plants kept in Samayeri, 5 have exhibited the disease including the one already reported, one of them was put on the platform between April and June 1931, two between April and June 1932, and two between October and December 1932 indicating that natural infection takes place at least in two seasons.

The platform plants show various types of injury which are being investigated.

(iii) *Cage experiments.*—The cage experiments detailed in the last bulletin (page 6, para 3) were continued. One plant showed the disease on 23-6-1932, *i.e.*, two months after caging. None of the remaining 114 has, so far, shown the disease, whereas 22 uncaged plants have succumbed.

This experiment has now been extended to Noganur R.F., where 14 plants in the spiked area (tested by lopping to see that no infection existed) have been caged with wire gauze cages.

VIII. Manurial plot.—The percentage of monthly incidence in the Aiyur manurial plot for the half-year ending October 1932, 0·49; November, 1932, Nil; December 1932, 0·62; January 1933, 0·62; February 1933, 1·91; March 1933, 1·58. The incidence is gradually declining year after year.

IX. Soil Profile Studies.—A few more soil profiles were examined during the half-year and the results corroborate the evidence already obtained.

X. Do plants get infected when under cover ?—Among the 50 sandal plants which were pruned in the last half-year, *i.e.*, in August 1932, one plant exhibited the disease during the half-year, *i.e.*, in January 1933. All others are healthy.

None of the 50 plants that were pulled out and stumped in pots have got the disease.

A. M. C. LITTLEWOOD
S. RANGASWAMI
M. SREENIVASAYA

Experiments conducted by the Madras Forest Department in collaboration with the Indian Institute of Science—II.

Experiments with chemicals.—Experiments reported in the previous half-year were continued. The methods of application have already been detailed in the earlier report.

A. In December last, the following treatments were carried out on spiked trees :—

Chemical applied	Trees treated	Trees dead
Sodium arseniate	9	9
Aluminium sulphate	5	2
Magnesium chloride	5	0

After a period of 3 months no further effect has been noticed.

B. In February again treatments were continued with a large number of chemicals. Two modifications were introduced in the experiment, first a few controls were run with each reagent on healthy plants, to determine its effect on them. It is assumed that the translocation of the poison will not be hindered in them and the effect when they are

killed, will then be due to the chemical again. On the other hand, if the spiked tree does not die, the result will then be traceable to defective translocation. Another change was effected in the method of application. In addition to girdling, an equal number of trees were selected, in which incisions were made around the stem at very short distances. This method has certain advantages over the girdling one, in that it helps the translocation of the chemical to all parts of the plants.

Similar treatments were made on healthy plants also. The results are summarised in the following table :—

Treatment done in February 1933 *and results after* 10 *days.*

Serial No.	Name of chemical	Method of treatment	No. of trees treated	No. of trees with foliage dried
1	Atlas solution	Girdling	10	9
	Do.	Incision	10	10
2	Atlas substitute No. 3	Girdling	5	5
	Do.	Incision	5	5
3	Do. No. 4	Girdling	10	9
	Do.	Incision	10	8
4	Do. No. 5	Girdling	10	10
	Do.	Incision	10	10
5	Arsenic acid	Girdling	6	6
	Do.	Incision	6	6
6	Sodium arseniate	Girdling	10	8
		Incision	10	2
7	Sodium chlorate	Girdling	10	8
	Do.	Incision	10	10
8	Sodium chlorate and Calcium chloride	Girdling	6	6
	Do.	Incision	6	6
9	Alkaline copper solution	Girdling	6	1
	Do.	Incision	6	2

Serial No.	Name of chemical	Method of treatment	No. of trees treated	No. of trees with foliage dried
10	Sodium silicoflouride	Girdling	5	0
	Do.	Incision	5	1
11	Ammonium thiocyanate	Girdling	6	4
12	Iron chloride	Bunging into holes	5	0
13	Ammonium sulphate	Girdling	6	0
	Do.	Incision	6	0

Necessary controls were run.

It is evident from the above that arsenic is the most effective in killing spiked trees although the killing is largely determined by the excess amount of the alkali which is used to dissolve the arsenous acid. Atlas substitute No. 3 was almost an exact substitute of 'Atlas' and is found to be very effective, in contrast to the patent solution. The result is extremely satisfactory with all the arsenic compounds applied during this period. Atlas substitute No. 5 deserves particular mention because there was no free arsenic in the preparation and the concentration of the arsenic was high. Based on the above results, stock solution of a new arsenical preparation has been made. Portions of these containing several spreaders such as soaps, saponins, etc., are ready for treatment and treatments with these will be carried out immediately.

Next, in order, the chlorates are effective in killing the diseased trees, the method of girdling and treating, being more useful than the incision method. Among the ineffectiveness are ethylone chlorohydrin, alkaline copper, iron chloride and ammonium compounds. It is necessary at this stage to point out that the effect of the poison is largely determined by the condition of the diseased plant. In a completely diseased plant, the effect is generally delayed and sometimes negative.

Translocation.—In the case of effective treatments, the leaves first wither and then the plants die. Experiments were initiated to test the infectivity of these drying leaves. Such specimens were grafted on to healthy sandal plants in pots, to find out if they were infectious and, if so, till what period. Results are awaited.

Experiments on the curing of spiked plants.—The object is to cure diseased plants through application of chemicals, when the disease is in incipient stages. With this end in view, diseased twigs were immersed in extremely dilute solutions of arsenicals and exposed to the sun to induce transpiration through leaves. It is assumed that the active constituent will be absorbed along with the water rendering the tissues innocuous by precipitating the active principle in the diseased specimens. Grafts from these have been made to test the infectivity of the bark at various distances. Suitable controls have been run.

S. RANGASWAMI
A. V. VARADARAJA IYENGAR

Coorg Experiments.

Results of lopping apparently healthy sandal.—In July 1932, 404 *apparently* healthy sandal trees were lopped in the old Chinnanahalli manurial plots to determine if any of them were masking the disease. 141 trees have so far been reported to be definitely 'spiked'. The symptoms started to manifest themselves from July 1932 onwards with the flush of new leaves. This works out to 35 per cent.

Those of the plots that prior to pollarding contained the fewest number of 'spiked' trees or rather had the largest number of *apparently* healthy trees are the ones which now show the greatest number of 'spiked' trees.

Pollarding of sandal in the old manurial plots at Chikkabettakeri was carried out in August 1932, but here no trees have so far shown any symptoms of 'spike'.

Both the above areas lie within the 'spike' zone.

Ecological survey.—A quantitative recording of the flora was carried out in 9 out of 20 strips in the Doddamolthe sandal area (a non-spiked area in Somwarpet Range). The detailed statement in this connection has already been sent.

Seed selection and testing.—Seeding has been bad this season and seed from the required localities could not be collected. One pound of seed from healthy trees in Chikkabettakeri and one pound from the heavily spiked Fraserpet Fort area were, however, collected and sent to the Indian Institute of Science, Bangalore.

Fresh outbreaks of 'spike'.—During the half-year, one case of 'spike' was noticed in Kyasaralli village on 14th November 1932 and two cases in Aigoor village since December 1932 in Somwarpet Range. The nearest spiked area is 3 miles away from the former village and 1½ miles away from the latter. All the three trees were uprooted.

Six fresh cases of 'spike' were noticed in the Bambookadu sandal plantation in addition to the one mentioned in the report for quarter ending 30th June 1932. All these trees have been uprooted. Five of these were within about 50 ft. from those spiked and uprooted last year and one about 300 ft. away. The trees lopped by Mr. Sreenivasaya have not shown any symptoms of 'spike' as yet.

The rains continued till the end of November 1932.

H. G. HICKS

Experiments conducted by the Indian Institute of Science. Laboratory Experiments—I.

I. Nursery.—*Seed testing.*—The proportion of 3 and 4 venated varieties in sandal seeds from various sources has been found. Generally the 4 venated seeds occur in much smaller proportions to the extent of 10 to 20 per cent.

Both varieties can be obtained from the same individual sandal plant and often from the same bunch of fruits. The haustorising power and the root system of sandal seedlings raised from four venated seeds, on the average are greater. Their actual resistance to artificial transmission has not yet been determined.

Seeds from Timor Islands (Malaya) obtained through the kind courtesy of Mr. Dyson, have been examined. The seeds contain a ovular cucumber-shaped variety which occurs to the extent of nearly 30 per cent. of the total number.

About 23 per cent. of the oval shaped seeds constitute the 4 venated variety. These seeds have been shown and the average percentage of germination is nearly 20 per cent., their root systems and haustorising power have not been investigated.

II. Transport of the infective agent.—With a view to visualise the transport of the virus, dyes, eosin and malachite green were injected

into the sandal plant. They were used for injecting the host plant also to see if the transport of nutrients from the host to the sandal could be determined. These experiments have met with great success. It has now been possible to explain why we meet with partially spiked plants where for months one finds certain parts of the plant continuing healthy. We can now account for the localization of the virus and the transfer of the virus to associated sandal plants. The absorption of nutrients from the host can be demonstrated. This technique may be of some value in determining whether a plant nearby is acting as a host to sandal or not under sylvicultural conditions, without digging or in any way interfering with the root system.

Immunisation studies.—Grafting of sandal plants with sub-lethal doses of infective material, has been carried out with a view to immunise them against the disease. The first dose has not produced the symptoms on defoliation. A second dose of infection will be given during this quarter.

Symptomology of disease-masking plants.—A detailed study of the records relating to the plants at the Aiyur manurial plot has been made with a view to determine the symptoms of disease-masking plants. It has been found that disease-masking plants respond to the influence of season in a different manner from the healthy plants. The period of flowering and fruiting of a disease-masking plant is extended far into the season of drought, while healthy plants normally complete their fruiting by January. In other words, immature green fruits are to be found in disease-masking plants during the months of February and March, during which period the healthy ones would be putting on vegetative growth. The reliability of employing this symptom is now being tested under field conditions.

M. SREENIVASAYA

Experiments conducted by the Indian Institute of Science.—II.

In continuation of what has been already reported, interesting observations have been made with regard to the organic acids. The healthy leaves contain chiefly malic and oxalic acids, while the diseased ones contain succinic, malic and oxalic acids. The quantities in which these are occurring are important.

Distribution of organic acids as percentages on dry weight.

No.	Condition of the plant	Malic	Oxalic	Succinic
I.	Healthy	0·27	0·79	..
	Spiked	0·19	0·34	0·75
II.	Healthy	0·31	0·84	0·005
	Spiked	0·24	0·24	0·62

In the water extracted residue, treatment with dilute sulphuric acid and extraction with ether, yielded a mixture of oxalic and malic acids in the healthy specimens and oxalic acid and a trace of malic acid in the affected ones. The presence of succinic acid and the considerably diminished quantity of oxalic acid is a significant feature of diseased condition.

Analysis of wood treated with Atlas.—It has been found in the present quarter that the oil steam distilled from heartwood treated with Atlas solution has no arsenic in it. Seven samples were examined and this was confirmed. In three cases there was arsenic detectable in the condensed water.

Arsenic distribution in Atlas treated plants and sandalwood oil.

Number of Plants tested	Arsenic in percentages in wood	Arsenic in the condensed water
1	0·00032	0·00002 gr.
2	0·00018	Nil
3	0·00021	Nil
4	0·00010	0·00002 gr.
5	0·00029	0·00004 gr.
6	0·00008	Nil
7	0·00004	Nil

Preparation of Atlas substitutes.—Though iron and copper salts are known to be detrimental to plants, it has been found that they have no effect on the diseased plants. The only chemicals useful in the destruction of such plants are the arsenicals, the patented Atlas solution and the chlorates. Arsenic in effective concentrations are decisive in their action. Attempts have been made to standardise an arsenical preparation and a stock solution has been prepared. To aliquots of these several penetrating agents such as acids, alkalies, soap, saponins, etc., have been added and are ready for treatment.

A. V. VARADARAJA IYENGAR

Half-yearly Report on the Spike Disease Investigation for the period ending 31st March 1933.

Five artificially infected pot-cultured sandal plants, which did not manifest the disease even after six months, were pruned and three of them showed the disease with the growth of new flush. The other two have continued healthy. The material from these disease-masking plants was collected, dried and powdered and preserved in bottles for analysis. Table I gives the details of grafting, pruning, etc., with regard to the plants.

TABLE I.

Plant No.	Date of grafting	Date of pruning	Condition of plant after pruning
855	14—7—1932	23—1—1932	Healthy
840	13—7—1932	,,	,,
843	11—7—1932	,,	Spiked 20–2–1933
839	,,	,,	,,
835	,,	,,	,,

The results of analysis of the leaves and stems of the disease masking as well as those that appear to have resisted the disease are given below:—

TABLE II.

	On percentage of moisture free material				On per cent. ash			
	Disease resistant		Disease masking		Disease resistant		Disease masking	
	Leaves	Stems	Leaves	Stems	Leaves	Stems	Leaves	Stems
Total Nitrogen	1·22	0·99	1·56	1·24	..	..	..	..
Ash ..	8·18	3·49	7·29	3·87	100	100	100	100
P_2O_5 ..	0·30	0·23	0·46	0·29	3·77	6·60	5·75	6·82
CaO ..	1·75	0·97	1·56	0·99	21·40	27·72	19·35	21·69

It will be seen from the Table that nitrogen and phosphorus are greater in the disease masking plant while calcium is lower than the plant which has resisted the disease whether it be leaves or stems. This corresponds to the condition of a spiked plant. Study of the distribution of the nitrogenous constituents is in progress.

Y. V. SREENIVASA RAO

Entomological Investigations by the Forest Research Institute. Work done at the Indian Institute of Science.

Work proceeded along the lines discussed in the last report, no definite evidence of the transmission of spike-disease by any species of insect being obtained. A detailed statement of all the experiments conducted to date is included in the annual report submitted to the Forest Entomologist, which will also be placed before the next Spike Conference.

Stock and Mass Infection Cage.—There were slight modifications in procedure. The two cages were converted into one, and about one-third of the healthy sandal plants in pots were transplanted in the ground. It was felt by the Working Committee that these changes would increase the prospects of success.

We have not yet succeeded in raising the fauna of this cage to the point where the non-appearance of spike in healthy plants could be regarded as a conclusively negative result. One assistant spends most of his time collecting insects in the vicinity of Bangalore for this cage, and another is similarly employed at Javalgiri, but the material obtained is insufficient, particularly as heavy demands on the stock are made for other experiments. It follows that more collecting staff (chiefly coolie labour) is necessary, and a small stock cage at Javalgiri, which would save the losses and expense incurred in frequent transit and serve as a relaying station, is also recommended. The ratio of spiked to healthy plants in the cage continues to militate against its utility as a transmission experiment.

Group experiments.—At the suggestion of the Working Committee, these experiments are miniature replicas of the Mass Infection experiment, differing only in that (1) the mass is restricted to a particular

group or combination of groups, and (2) the ratio of spiked and healthy plants is 50 : 50. In our opinion, these experiments would be improved if each cage contained four spiked plants and two healthy plants, but the scarcity of spiked plants does not permit this at present. The insect groups previously mentioned continue to be employed for these experiments, additional specimens being added from time to time. The healthy plants are pruned every two months.

At Mr. Sreenivasaya's suggestion a small mass infection experiment with insects collected from the mound plants at Javalgiri, where spike has newly appeared, was also conducted in one of the group cages. Insects were collected both in the mornings and evenings and were sent to Bangalore every fortnight for three months for introduction into the cage. Heavy defoliation of both spiked and healthy plants in the cage has occurred and the healthy plants have been pruned. Results are awaited.

Individual experiments.—Experiments with individual species, both in cages and in sleeves, have been continued. The intensified form of specific vector experiment mentioned on page 13 of the last report has been concluded in the case of *Moonia variabilis* and *Acropona walkeri* with negative results. Unfortunately, however, the number of specimens used for these experiments was not as large as we originally expected.

It has been noted that in a majority of cases the feeding of spike-fed specimens of *Moonia*, *Petalocephala* and *Acropona* on healthy plants produces a condition that bears a distinct resemblance to spike. In control experiments (lacking the spike-fed factor) similar results have not occurred. Grafting from these spike-resembling plants has been done in a few cases, so far without results. These results are generally regarded as promising and we are accordingly investigating them further.

Transmission experiments, employing laboratory methods, have also been commenced as a contribution to the speeding up of the number of experiments conducted. Sap is extracted from spiked leaves and kept in cold storage for use as required. The experiments consist in feeding suctorial insects on diseased sap through collodion tubes, each of which is enclosed with a number of insects in a beaker covered with a piece of muslin. After a feed of 15 to 20 hours in this manner, the insects are transferred to healthy plants, and the experiments are continued as in the case of other specific vector experiments. We have found that suctorial insects feed readily on the sap contained in the membranous tubes, and intend to continue the work on a large scale.

Routine work.—Accompanied by Mr. Sreenivasaya, we visited the Javalgiri mound and plantation area in connection with the appearance of spike in the mound plants and the high incidence of scars on them. Notes on the results of the inspection and on the cloth-cages at Javalgiri have been submitted to the Committee.

The need for an adequate supply of healthy plants has resulted in the transplantation of 150 stumps from the sandal area of the Indian Institute of Science to pots that are being tended in the grounds of the Insectary.

Life-history work has been continued, and records of the life-cycle of *Flata ferrugata* were completed in the period under review.

End Results.—In spite of considerable handicaps the last year has seen a new, and we hope a more productive, orientation of local entomological work on the spike disease problem. Apart from the maintenance of the Mass Infection experiment, 17 group experiments and 290 specific vector experiments, in cages and sleeves, have been conducted, the majority being now concluded. All the common species found on sandal have been used for these experiments, special attention being paid to Jassids, Fulgorids, Aphids and Weevils. The work has not yet provided positive or definitely negative results, but we have reached a stage where, by concentration, elimination, and the elaboration of the Mass Infection experiments, we should be able, within a year, to assess the rôle of insects in the spike disease problem.

M. APPANNA
CEDRIC DOVER

Entomological Investigations by the Forest Research Institute. Work done at Dehra Dun.

Qualitative Insect Collections.—Continuing the work referred to on pp. 15–17 of the VIth Progress Report, the study of the fauna of six host-sandal combinations in healthy and spiked areas has been completed and the group Zizyphus-sandal remains to be done. The total number of insects listed and identified amounts to 21,660. The *Membracidæ* have been studied. *Otinotus oneratus* Dist. appears to be one of the common membracids found on sandal in the quantitative collections, but in the host-sandal enumerations this species is absent

in four combinations and occurs very rarely on Pterolobium-sandal and Scutia-sandal. In the combination studied, *Coccosterphus tuberculatus* Mots. takes the first rank and occurs abundantly in all combinations except sandal-lantana on which it is absent. It is relatively more abundant on both host and sandal in spiked areas than in healthy areas.

Fauna of sample plots.—Reports on sandal insects from nine specialists which deal with 148 species of beetles, 69 species of bugs and 18 species of *Neuroptera* have been sent to press. The analysis of the more important species of *Fulgoridæ*, *Jassidæ*, etc. in the Kottur Yellagiri sample plots has been completed. Analytical studies of the *Cicindelidæ*, *Membracidæ* and *Rhipiceridæ* from all the sample plots have been made and work on *Bruchidæ*, *Carabidæ*, *Chrysomelidæ*, *Chrysopinæ*, *Fulgoridæ*, *Jassidæ*, *Lepidoptera*, and *Mantispinæ* is nearing completion. Records of seasonal incidence and regional distribution of these families are in course of being written up with the assistance of Messrs. G. D. Bhasin, G. D. Pant and M. Bose.

Incidence of sandal insects in observation areas of North Salem.—Statistical information is now available regarding the relative abundance of insects in plot Nos. 14, 20 and 21 located in the observation areas of Cairn No. 53, at Javalgiri; Nyamasandiram Agraharam and Mahadeswarangudi at Aiyur; where the Indian Institute of Science made extensive observations during the period of the sandal insect survey work. Of the total number of sucking insects collected during the course of a year about one-third occurred in plot 20, a little more than a third in plot 14 and somewhat less than a third in plot 21. Jassids were equally abundant in all the three plots and consist of about three-tenths of the *Hemipterous* population of the plots. *Fulgorids* were as abundant as *Jassids* in plot 14, but only three-fifths as abundant in plots 20 and 21. Plot 21 in Mahadeswarangudi according to Mr. Sreenivasaya and others is a resistant area, hence the presence or absence of a vector is a factor of small importance in the spread of the disease. Comparison of the incidence of suspected vectors can therefore be restricted to plots 14 and 20.

In view of Mr. Sreenivasaya's finding that the intensity of attack on sandal as measured by scars is roughly proportional to the disease incidence, it may be stated that the most abundant scar making species are *Acropona walkeri* (equally numerous in both areas), *Petalocephala nigrilinea* (one and a half times as numerous in plot 20 as in plot 14), *Moonia albimaculata* (one and a half times as numerous in plot 14 as in plot 20); *Bythoscopus indicus* and *Ledra mutica* are relatively much less abundant, but more numerous in plot 20 than in plot 14. Together,

these five scar making species form about a quarter of the *Hemipterous* population in each plot. The incidence of spike was practically the same in each plot.

If the selection of the possible vector of spike disease is to be based on the species occurring most rarely on sandal, then the choice should fall on *Ledra mutica* Fabr. This species feeds on both healthy and spiked sandal and also makes scars on sandal shoots during oviposition, smaller in size but similar to those made by *Petalocephala nigrilinea* Walk.

Laboratory work.—Papers on a sandal Fulgorid *Eurybrachys tomentosa* Fabr, and on a very common sandal Jassid *Petalocephala nigrilinea* Walk, have been submitted for publication.

N. C. CHATTERJEE

713-33 Printed at The Bangalore Press, Mysore Road, Bangalore City